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The American Journal of Alternative Agriculture provides an international forum for original research articles on the biological, physical, social science and policy aspects of alternative agriculture. The journal particularly focuses on multidisciplinary studies and covers the character and potential of alternative, sustainable and organic farming systems.

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The ecological economics of insecticide use associated with the Maine potato industry, based on a producer survey

C.R. Ziegler, D.W. Donahue, F.A. Drummond, and S.N. Smith

Abstract. *Environmental risks and costs associated with insecticide applications in Maine potato farming have been characterized and estimated using an Aroostook producer survey. The results of this study allow for comparison of pest management strategies based on producer concern for various aspects of the environment, including water quality, human health and animal safety. 'Willingness to pay' survey methodology was used to acquire an environmental cost range for insecticide use. Maine potato producers are willing to pay between \$1.00 acre^{-1} (one acre = 0.4047 ha) and \$26.80 acre^{-1} to avoid or reduce environmental risk associated with a single insecticide application. The Aroostook producer survey indicates that producers with small farms are generally willing to pay more to avoid or reduce environmental risk than producers with large farms. Mean Maine potato farm size has more than tripled over the past 40 years; therefore, concern for environmental quality on Maine potato farms could be decreasing.*

Key words: contingent valuation, environmental quality, pest management, willingness to pay

Introduction

Between 1958 and 1998, Maine potato (*Solanum tuberosum*) acreage decreased from approximately 147,000 acres to 70,000 acres, (one acre = 0.4047 ha) and the number of Maine potato farms decreased from over 5800 to under 600 (Maine Cooperative Extension, 1998; USDA, 1992, 1995). (Note: acre is used as the area unit in this study for convenience since it was a survey of US farms where acre is the standard unit of field size.) While total US potato acreage has remained relatively constant, that in Maine continues to decrease, and current Maine potato producers have larger farms than those in the past (Figs. 1 and 2).

Maine potato production presents risks to the environment, and these risks may be linked to economic objectives. As stated previously by Marra (1996):

> The 'bottom line' may be the most important result to report from a farmer's point of view. Even if a production strategy is much less harmful to the environment, if it does not provide enough net return, then it is not likely to be widely adopted by farmers. While many farmers are willing to give up some profit in exchange for less environmental damage, they still must make enough profit to survive in the long term. Therefore, the economic aspects of any production system are an integral part of its measure of sustainability.

Colorado potato beetle [*Leptinotarsa decemlineata* (Say)] and potato-infesting aphids such as the green peach aphid [*Myzus persicae* (Sulzer)], the potato aphid [*Macrosiphum euphorbiae* (Thomas)] and the buckthorn aphid [*Aphis nasturtii* (Khaltenbach)] threaten Maine potato production. Maine potato producers control insect pests, such as Colorado potato beetle and aphids, with insecticides, which in turn may threaten environmental quality. The goal of this study is to define the environmental risks and costs associated with the use of insecticides on Maine potato farms, based on a combination of scientific relationships and the values of Maine potato producers.

Several efforts attempt to characterize environmental risks associated with agriculture. Becker et al. (1989) characterize the risk of pesticides to water quality. This work resulted in a method for ranking pesticide risk to surface- and groundwater dependent on pesticide chemistry and site-specific soil characteristics. Specifically, pesticide soil half-life, soil sorption and water solubility are cross-referenced with soil properties known to affect pesticide movement and persistence, such as hydrologic conductivity and texture. Our study seeks a more holistic definition of environmental risk by including additional parameters such as human and animal health.

Kovach et al. (1992) characterize the risk of pesticides to 11 environmental categories, including water quality, human health and health of other non-target animals, with a single number or Environmental Impact Quotient (EIQ). Parathion, a highly toxic organophosphate insecticide, has an EIQ of 104.4, while *Bacillus thuringiensis*, an insect pathogenic bacterium naturally

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present at a relatively low density in soil, has an EIQ of 13.5. The EIQ method ranks pesticides based on effects associated with a larger portion of the environment, that is, 11 environmental categories, in contrast to water quality alone. Unfortunately, several flaws plague EIQ methodology, as summarized below and reported elsewhere (Dushoff et al., 1994; Mullen, 1995). The EIQ method depends on a formula that weights components of the environment against one another. Determinations such as this hold implicit value judgements (Dushoff et al., 1994). Who should decide how much more or less important it is to protect the population density of bees (superfamily *Apoidea*) as opposed to human reproductive functions, and who should translate that proportion of importance into terms of an EIQ? Furthermore, the single EIQ number used as an index is relative only to other EIQ numbers; that is, the EIQ is not measured in known or otherwise understood units, such as dollars.

Another attempt at environmental risk assessment of pesticides uses willingness to pay (WTP) survey methodology to scale and estimate the risks of pesticides to eight environmental parameters in terms of dollars. Higley and Wintersteen (1992) first developed this application of WTP for environmental risk from pesticides. They surveyed farmers for subjective information necessary in making risk and cost determinations, and

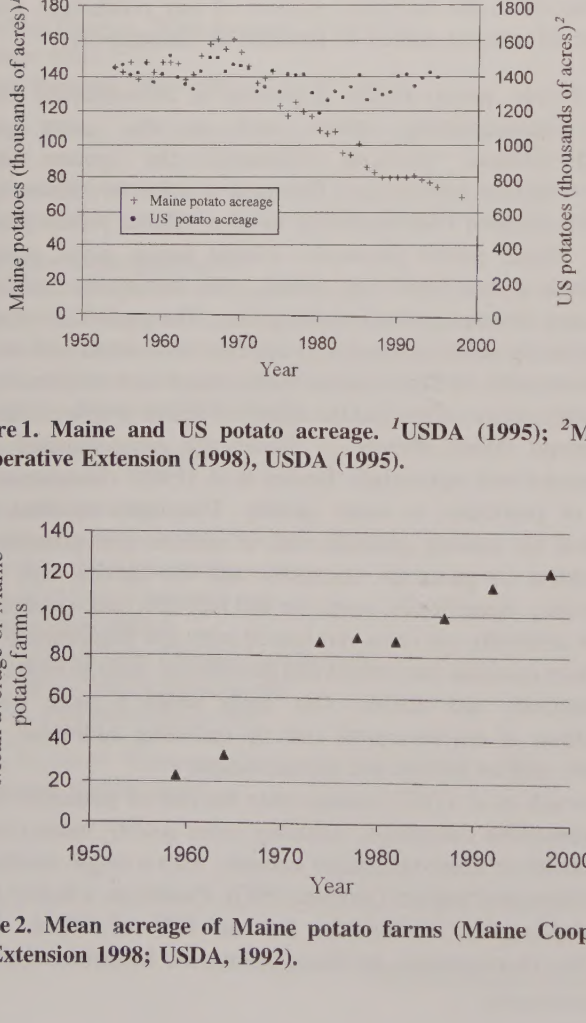

Figure 1. Maine and US potato acreage. [1]USDA (1995); [2]Maine Cooperative Extension (1998), USDA (1995).

Figure 2. Mean acreage of Maine potato farms (Maine Cooperative Extension 1998; USDA, 1992).

combined this with scientific information about pesticide environment interactions. The Higley and Wintersteen produce survey (HWPS) was sent to 8000 field-crop producers in th north-central United States (with 21.8%, or 1741, usable survey returned), asking how much these producers would be willing t spend or accept in yield losses to avoid high, moderate and lo risks from pesticides. Survey participants were also asked t rank the importance of eight environmental categories: surfac water, groundwater, aquatic organisms, birds, mammals, bene ficial insects, human acute toxicity and human chronic toxicity These eight parameters resemble the 11 categories of the EI (Kovach et al., 1992), all of which can be broadly characterize as water quality, non-target organisms and human health (Higle and Wintersteen, 1992).

Higley and Wintersteen (1992) note that WTP estimates wi differ depending on location, time and commodity—stressin the need for future surveys. Recently, another WTP surve (Mullen consumer survey, or MCS) was sent to 3000 U residents or consumers (with 15.4%, or 404, usable survey returned), asking participants how much they would be willin to pay as an increase in monthly grocery bill or as an increase i yearly federal income tax in order to avoid risk to th environment from pesticides (Mullen, 1995; Mullen et al 1997). Additionally, the MCS asked participants to rank th importance of the eight environmental categories, which wer also used in the HWPS.

Our work reports on a WTP survey designed for the purpos of quantifying environmental risk and costs for the Maine potat industry. The objectives were to: (1) estimate the environmenta costs of Maine potato industry insecticide use at varying leve of risk; (2) determine how best to allocate social concern for th environment by scaling eight environmental categories relativ to each other; and (3) demonstrate how environmental costs an scaling factors for insecticide use might be used in the Main potato industry and what this information might indicate for th industry.

Aside from insecticides, conventional Maine potato produc tion relies on the following petroleum-based inputs: vehicl fuels, fertilizers, herbicides and fungicides. In addition to risk from those purchased inputs, agriculture poses other possibl environmental risks, such as erosion and contaminated surfac water flowing through non-agricultural regions and out o Maine. It is neither reasonable nor possible to determine all o the environmental costs due to a human action such as a agricultural practice. Our research seeks a *partial* estimate of th environmental costs associated with Maine potato farming b focusing on insecticides.

Methods

Approximately 92% of Maine potato production occurs Aroostook County, the northernmost county of Maine; therefor producers from this county (approximately 450) were chosen representative of the Maine potato industry. To ensure efficie use of project funding with a desired sample size in excess of 2 usable returns from Aroostook County potato producers, th Aroostook producer survey (hereafter called APS) was designe

to be distributed and collected in person at the Thirteenth Annual Maine Potato Conference and Trade Show, 21–22 January 1998, held in Caribou, Maine.

The APS possesses two parts: a written section filled out by producers, and an interview section filled out by the first author. The written section was distributed to approximately 55 potato producers attending the convention. The APS written section shares the general format of the WTP and environmental category scaling questions of the HWPS (Higley and Wintersteen, 1992). The written section of the APS can be used on its own, and was designed to attain quantitative information including WTP, environmental scaling factors and demographic data such as farm size. Figure 3a and b display a portion of the written section.

If estimation of WTP is purely a quantitative matter, who can pay and how much, then it is appropriate to trim the APS WTP data in order to exclude less realistic responses (e.g., high outliers). On the other hand, if WTP is considered to be a reflection of the feeling of the total farming community about insecticides in the environment, then all responses should be given equal weight. Predetermined WTP values such as an upper limit were not provided for the participants of the APS. Mitchell and Carson (1989) suggest the use of robust statistical estimators to reduce the effect of possible outliers of unbounded WTP results. One such estimator is the α-trimmed mean (μ_α), given as:

$$\mu_\alpha = (X_{(n\alpha)+1} + \ldots + X_{[n-(n\alpha)]})/[n - 2(n\alpha)] \quad (1)$$

where X_n represents the nth value of the ordered responses, and $0 \leq \alpha < 0.5$. Essentially, a standard mean is an α-trimmed mean with an α of zero, and the median is an α-trimmed mean with α equal to 0.5. An α-trimmed mean using an α equal to 0.1 indicates that the lowest 10% and highest 10% of responses are removed, and a mean is calculated for the remaining responses. We chose to analyze the APS WTP responses with acre-scaled and non-acre-scaled mean, α-trimmed mean ($\alpha = 0.1$), and median calculations.

Upon completing and handing in the written section, producers were asked to participate in the interview section if the interviewer was available—that is, the interviewer was not currently administering this part of the survey to another producer. The interview section consisted of general open-ended pest management questions.

In order to determine the APS sample representation of the Maine potato producer population and the general nature of the sample with respect to environmental stewardship, some results of the APS were compared to those from another survey. On 30 January 1998, the University of Maine Cooperative Extension office mailed a survey to 500 Maine potato producers with the annual request for pesticide use information. Our APS and the Cooperative Extension survey share five questions (Fig. 3b).

Results and Discussion

For the written section of the APS, 34 of 55 surveys were handed in (61.8% return); typical time spent on this section ranged from 4 to 15 minutes. Of the 34 written-section participants, 12 completed the interview section. Typical time spent on the interview section ranged from 5 to 20 minutes, depending on producer interest in environmental and pest management issues. Of the 500 mailed Cooperative Extension surveys, 62 usable surveys were returned (12.4% return).

Respondents

The APS has representation of Maine potato producers from each of the three production categories: potatoes for processing, seed potatoes and fresh market potatoes (Table 1 and Question #1 of Fig. 3). The sample has a relatively high percentage of seed potato acreage. In general, seed producers use more insecticides and other intensive management practices because fresh market and process potatoes can withstand more pest attack than seed potatoes, while retaining market value. The distribution of producers surveyed relative to the actual population of producers results in a discrepancy suggesting that the APS sample might be skewed toward more conservative (lower) estimates of WTP than the general Maine potato producer population, since this sample of producers relies more heavily on insecticides.

Representativeness can also be assessed using answers to the five shared questions found in both the Cooperative Extension survey and the APS (Figs. 3b and 4). In general, survey participants disliked shared Question #4, which asks: 'Please rank the following in order of importance to your farming operation: (*1 = most important, 5 = least important*) Preventing soil erosion, Satisfying buyers, Increasing future production, Protecting water quality, Meeting financial obligations' (Fig. 3b). Of the 95 responses to Question #4 (from both the APS and the Cooperative Extension survey), 6 producers refused to answer and 10 producers ranked all endeavors at the same level of importance, that is, 'most important'. Aside from Question #6, shared question results indicate agreement between survey samples. The mean response for the Aroostook Producer Survey Question #6, which asks producers how important protecting the environment is in their daily lives, is over one and a half times greater than that of the Cooperative Extension survey (3.67 versus 2.32, respectively). Quantitative analysis of Question #4 was excluded from the shared question comparison.

Of the 12 interview section participants, three producers use a combination of non-chemical (i.e., biological and physical control) and chemical insect pest control; nine producers use 100% conventional chemical control. Generally, the interview participants could point to environmental quality improvement on their farms over the past 20–30 years. Environmental quality

Table 1. Maine potato production distribution.

	Production type acreage (%)		
	Process	**Seed**	**Fresh**
Aroostook producer survey sample[1]	51.9	38.1	10.1
Maine potato grower population[2]	55.4	31.1	13.5

[1] From this study.
[2] Maine Cooperative Extension (1998).

(a)

1. What percent of your potato farming operation falls into these three categories:

   _____ % Process
   _____ % Seed
   _____ % Table Stock

2. Please rate how important you think it is to reduce or avoid risk from insecticides in each of the following environmental areas:

   0 = Not Important *2 = Important*
   1 = Slightly Important *3 = Very Important*
   4 = Critical

Environmental Area	**Lower ← Importance → Higher**				
Surface Water (streams, rivers, ponds and lakes)	0	1	2	3	4
Groundwater (wells and aquifers)	0	1	2	3	4
Fish	0	1	2	3	4
Birds	0	1	2	3	4
Beneficial Insects	0	1	2	3	4
Chronic (long term) Human Health	0	1	2	3	4
Acute (short term) Human Health	0	1	2	3	4
Other Mammals	0	1	2	3	4

3. One way to address environmental risks from insecticides is to decide how much avoiding certain levels of risk would be worth. Growers and consumers of farm products may be willing to spend more to reduce or avoid the environmental impact of an insecticide. This additional expense could be used to buy a safer insecticide, **or** the expense could be viewed as greater yield loss (in terms of dollars) tolerated before using an insecticide. For **one** application of an insecticide, how much would you be willing to spend on such an additional cost...

   ...to avoid high risks to the environment $ _____ per acre
   ...to avoid moderate risks to the environment $ _____ per acre
   ...to avoid low risks to the environment $ _____ per acre

(b)

4. Please rank the following in order of importance to your farming operation:
   (1 = most important, 5 = least important)

   ____ Preventing soil erosion
   ____ Satisfying buyers
   ____ Increasing future production
   ____ Protecting water quality
   ____ Meeting financial obligations

5. In your judgement how do your farming practices compare to those of other Maine potato farmers with respect to preservation of the environment? (please circle one)

   Much worse Slightly worse Similar Slightly better Much better

6. How important do you consider protecting the environment in your daily life? (circle one)

   No consideration Some consideration Important Very important Critical

7. How well are you informed about the mechanics of composting? (circle one)

   I don't know 1 2 3 4 5 I'm well informed

8. What do you know about the benefits of composting? (circle one)

   I don't know 1 2 3 4 5 I'm well informed

Figure 3. Aroostook Producer Survey: (a) first three questions (from the front page of the written section) and (b) shared questions of th Aroostook producer and Cooperative Extension surveys (from the second page of the Aroostook survey written section).

improvement from the perspective of the producers often takes the form of noticing more wildlife on and around farms. Producers attribute this improvement to a heightened and growing sensitivity toward environmental concerns over the past three decades.

Participants showed signs of being defensive and threatened while taking the survey. This defensiveness was evident for most participants, but especially came to light during the administration of the interview section. Based on discussions with interview participants and other producers in the Maine potato industry, it would seem that producers feel restricted by government regulations and threatened by environmental activism. However, once producers began to talk about environmental issues, uneasiness subsided, and survey participants were glad to share their experience and knowledge about their lives as potato producers. In general, producers spoke of the environment from a sympathetic point of view; that is, they recognize environmental damage associated with conventional agriculture, and they would like to see less damage.

Willingness to pay question

Only 30 of the 34 written section respondents communicated usable answers for the WTP question (Table 2). Seven producers indicated that they were not willing to pay for any of the three levels of risk. Three producers indicated that they were willing to pay $100 or more for at least one of the three levels of risk. The range of WTP responses, from $0 to $300, suggests that mean WTP estimates for the three levels of risk might be sensitive to outliers.

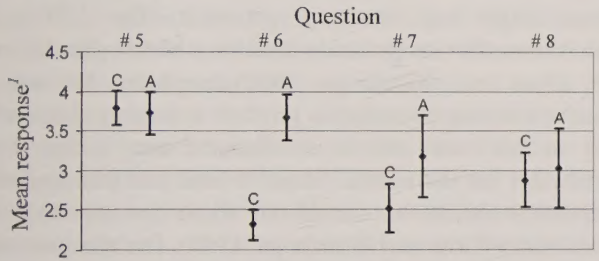

Figure 4. Shared question results of the Aroostook producer survey (A) and Cooperative Extension survey (C); error bars display 95% confidence intervals. [1]Responses for each question range from 1 to 5; for Questions #5 and #6, a number from 1 to 5 has been assigned to each of the five possible textual responses from left to right (see Fig. 3b).

All acre-scaled WTP calculations are lower than their non-acre-scaled counterparts, indicating that producers with larger farms are less inclined to pay environmental costs associated with insecticides. Non-acre-scaled α-trimmed means (α = 0.1) from the APS are quite similar to those values from the HWPS—both in magnitude and discrepancy among the three levels of risk (see Table 2).

APS participants were often confused and disturbed by the WTP question (Fig. 3a). A minority of the producers, generally those who were not willing to pay for environmental risk, thought that environmental cost was included in the material cost of insecticides and argued that chemical companies increase the price of chemicals that are likely to create future human health problems and related legal issues. Hutchins and Gehring (1993) make a similar argument, claiming that the costly registration process for insecticides is reflected in the material cost. Higley and Wintersteen (1997) disagree on the grounds that differences in pesticide material costs are not based on safety or differential registration costs. Furthermore, from theoretical and practical standpoints, arguments have been made against WTP survey methods for various reasons not discussed herein (see Arrow et al., 1993).

For the purposes of this analysis, further argument regarding the validity of WTP survey procedures and results will not be addressed on the following grounds: the APS indicates that the majority of Aroostook potato producers are willing to pay some amount of money to reduce or avoid risk to the environment in addition to their current production costs, and dialogue with survey participants uncovered a general feeling of sympathy for the environment, which producers felt was not being treated satisfactorily. Therefore, whether chemical companies are accounting for environmental risk or not, and whether or not

Table 2. Willingness to pay (WTP) question results.

			WTP or environmental cost estimates (dollars per acre and application) at three levels of risk:		
		Acre-scaled	High	Moderate	Low
Aroostook producer survey, $n = 30$	Mean (α=0.0)[1]	No	26.80	18.30	13.33
		Yes	19.01	12.90	9.97
	α-Trimmed mean (α = 0.1)[1]	No	12.67	7.25	6.25
		Yes	10.81	6.09	5.22
	Median (α = 0.5)	No	10.00	4.00	1.50
		Yes	5.00	3.00	1.00
H/W producer survey, $n = 1114$[2]		–	12.54	8.76	5.79

[1] Calculation of the α-trimmed mean as described by Mitchell and Carson (1989).
[2] Higley and Wintersteen (1992).

our economy is accounting for the environment in some other way, the APS results indicate that current treatment of the environment is suboptimal from the vantage point of Maine potato producers, with regard to insecticide use. An optimal situation might be defined as one for which all costs and returns are accounted. Current economic analysis of this agricultural system does not appear to be completely inclusive of the environmental costs associated with insecticide use.

Environmental scaling question

All 34 respondents of the APS answered the environmental scaling question (Fig. 3a). Analysis of variance suggests that at least one of the means for the eight environmental categories is statistically different ($\alpha = 0.05$; $P = 0.045$). Due to the low sample size and, in turn, a relatively low analysis of variance power (79.7%), conclusions about specific differences between environmental category means have not been made. However, the APS environmental scaling question produced similar ordinal rankings of environmental categories as the scaling questions of the HWPS and the MCS (see Table 3). The 'Other Mammals', 'Surface Water', and 'Groundwater' categories were ranked with high importance in each of the three surveys, while 'Chronic Human Health', 'Birds', 'Beneficial Insects' and 'Fish' were generally ranked low. 'Birds' received an identical ordinal ranking of 7 in each of the three surveys. The low ranking of 'Beneficial Insects' in the two producer surveys raises inquiry about how well informed farmers are about the positive affects of natural enemies on insect pest control.

Application

The results of the APS can be used to estimate an environmental cost range associated with insecticide use on Maine potato farms. Such costs can be used by producers to decide when and if a pesticide should be applied, as determined by an economic or action threshold (Pedigo, 1996). Als individuals responsible for establishing insecticide use regul tions might employ such cost estimates to make the determinations.

The model developed by Higley and Wintersteen (199 combined with information specific to the Maine potato indust can be used to estimate an environmental cost range. Mai potato producers are currently using imidacloprid, a popul chloro-nicotinyl insecticide marketed under the trade name Admire® and Provado®. The following example summariz how an environmental cost range can be determined f imidacloprid using the Higley and Wintersteen (1992) mod in combination with data from the APS and recent researc describing interactions between insecticides and the enviro ment.

First, levels of risk to the eight environmental categories we estimated for imidacloprid using the chemical databas EXTOXNET (1998). Methods for determining site-specif risk to water quality were derived from Becker et al. (198 and Goss and Wauchope (1990). Second, farm-specific inform tion must be acquired. In the case of Maine farms, approximate 85% of the soil types being used to farm potatoes have hig leaching potentials (USDA SCS, 1993), increasing the chanc of an insecticide reaching groundwater; therefore, this examp assumes high soil leaching potential. The USDA So Conservation Service Pesticide Leaching Matrix (Becker et a 1989; Goss and Wauchope, 1990) combines the soil an chemical leaching potential to produce a single rating—a hig rating in this case—which is translated into a high risk groundwater for the model. Slope of land and post-applicatio precipitation should be considered when determining risk surface water (Goss and Wauchope, 1990). For this generalize example, however, additional site-specific inferences will not b made; therefore, aside from groundwater, the other seven leve of risk will be based solely on information specific

Table 3. Environmental scaling question results from three willingness to pay surveys, measuring the relative importance of eig environmental categories.

	Mean ±SD[1]	Scaled importance[2] (rank)		
Environmental category	APS[3]	APS[3]	HWPS[4]	MCS[5]
Surface water	3.24 ± 0.74	0.1313 (3)	0.1267 (4)	0.1282 (
Groundwater	3.32 ± 0.81	0.1349 (1)	0.1336 (3)	0.1343 (
Fish	3.03 ± 0.80	0.1229 (5)	0.1182 (6)	0.1269 (
Birds	2.85 ± 0.82	0.1158 (7)	0.1162 (7)	0.1195 (
Beneficial insects	2.79 ± 0.99	0.1182 (6)	0.1130 (8)	0.1197 (
Chronic human	3.29 ± 0.84	0.1131 (8)	0.1196 (5)	0.1092 (
Acute human	3.21 ± 0.88	0.1301 (4)	0.1362 (1)	0.1259 (
Other mammals	2.91 ± 0.90	0.1337 (2)	0.1362 (1)	0.1362 (

[1] SD = standard deviation.
[2] Scaled importance values were determined by dividing each mean response by the sum of mean responses for each survey.
[3] APS = Aroostook producer survey.
[4] HWPS = Higley and Wintersteen Producer Survey (Higley and Wintersteen, 1992).
[5] MCS = Mullen Consumer Survey. Scaling factor averaged for three levels of risk for which it was asked in the Mullen consumer survey (Mullen, 1995).

imidacloprid. Adjustment of risk levels based on site-specific information is not a completely objective task; there will be exceptions that can only be accounted for by on-site experts, such as producers.

Once risk levels are determined, WTP dollar values assigned to these levels are multiplied by the environmental category scaling factors. The products are summed to yield an environmental cost range for imidacloprid. The low range environmental cost of applying imidacloprid is \$3.53 $acre^{-1}$ and the high range cost is \$20.96 $acre^{-1}$. A summary of calculations made for this example is given in Table 4. Excluding environmental costs and ownership costs (e.g., mortgage payments and property taxes), the total variable cost of growing potatoes in Maine ranges from approximately \$650 to \$850 $acre^{-1}$ (Gallandt et al., 1998). As shown through this example, a single application of imidacloprid adds an environmental cost ranging from 0.4% to 3.2% of the variable costs of growing potatoes.

Conclusions

Participants of the APS consider the environment important, and 77% of these producers are willing to pay to reduce or avoid risk to the environment. The results of the APS indicate that current conventional insecticide use within the Maine potato industry is suboptimal; that is, the economics of this industry do not sufficiently include environmental costs. The result is an industry in which the participants say one thing and do the other; Maine potato producers lack an adequate choice of options. If their individual financial goals are not met, then they must leave the industry and their livelihood. Given this and the ongoing trend described earlier (fewer Maine potato farms and larger Maine potato farms), the future will squeeze out those producers trying to appease individual economic and communal goals, while rewarding those producers who seek only to achieve individual economic goals.

The Aroostook Producer Survey WTP question brings to bear another question: If producers are willing to pay an additional cost on top of current management costs for environmental quality by using safer insecticides or by using less insecticides and accepting greater yield loss, then why are they not doing it? Sagoff (1988) summarizes the dilemma:

> Willingness to pay. What is wrong with that? The rub is this. Not all of us think of ourselves primarily as consumers. Many of us regard ourselves as citizens as well. As consumers, we act to acquire what we want for ourselves individually; each of us follows his or her conception of *the good life*. As citizens, however, we may deliberate over and then seek to achieve together a conception of *the good society*.

The economic goals of Maine potato producers appear to be at odds with their communal goals. Garret Hardin's 'The Tragedy of the Commons' (1968) might be changed to 'The Tragedy of the Option-less' for the case of the Maine potato industry, where '[a]s a rational being, each herdsman seeks to maximize his gain . . . Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited' (Hardin, 1968). The APS is evidence of agricultural 'survival of the fittest', where producers with larger farms are less willing to pay to reduce environmental risk (illustrated in Table 2). If this is to remain the nature of our competitive market system, and if the fate of the environment is to be decided by all, then environmental quality concerns must precede economic goals and not become a part of them. However, the current ecological or environmental economics trend is to internalize environmental costs within our conventional economic system. Maine potato producers were uncomfortable when asked to quantify these costs, and many simply disagreed with pricing the environment. Can anyone or any group of people adequately establish the monetary value of environmental health, including the health of humans?

Although pricing the environment may not be an adequate long-term method of accounting for environmental quality, a reasonable interim method may be to internalize environmental cost estimates in agricultural cost–benefit analyses, while society searches for, and attempts to implement, more acceptable methods. Economic injury levels (EILs), essentially cost–benefit analysis equations, are used to determine the point at which it is economically advantageous to apply a pesticide. It has been proposed that environmental costs could be combined with conventional costs associated with managing a farm to produce an environmental EIL (Higley and Wintersteen, 1992).

A user-friendly computer program has been developed to work through the environmental cost model described by Higley

Table 4. Imidacloprid: calculation of an environmental cost range for a Maine potato farm (single application on 1 acre).

Environmental category	Imidacloprid risk level	Site specific adjusted risk level	High-range WTP (\$)	Low-range WTP (\$)	Importance scaling factor	High-range cost estimate (\$)	Low-range cost estimate (\$)
Surface water	High	High	26.80	5.00	0.1313	3.52	0.66
Groundwater	Moderate	High	26.80	5.00	0.1349	3.62	0.67
Fish	Moderate	Moderate	18.30	3.00	0.1229	2.25	0.37
Birds	High	High	26.80	5.00	0.1158	3.10	0.58
Beneficial insects	Low	Low	13.33	1.00	0.1182	1.58	0.12
Chronic human	Moderate	Moderate	18.30	3.00	0.1131	2.07	0.34
Acute human	Moderate	Moderate	18.30	3.00	0.1301	2.38	0.39
Other mammals	Moderate	Moderate	18.30	3.00	0.1337	2.45	0.40
Total						20.96	3.53

and Wintersteen (1992) (Ziegler, 1999; Ziegler et al., 2000). The program provides users with alternative pest-management strategies in lieu of conventional economics, environmental costs (described herein) and insect pest ecology. The program may benefit a wide range of users, including researchers, Cooperative Extension professionals and potato producers.

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Farmers' market research 1940–2000: An inventory and review

Allison Brown

Abstract. *The number of retail farmers' markets in the USA increased dramatically in the twentieth century, with a burst of growth experienced after the passage of Public Law 94-463 (PL 94-463), the Farmer-to-Consumer Direct Marketing Act of 1976. This article inventories the literature since the Second World War on retail farmers' markets and direct marketing in North America. The inventory includes some lesser known studies from 1970 to 1985. The reports are grouped into four categories by topical area: consumers and vendors, economic impact, social impact and farmers' markets as research sites. Overall, the literature on farmers' markets is found to be scant, leaving ample room for new and exciting explorations of this venerable institution.*

Key words: direct marketing, PL 94-463, produce marketing, retail farmers' markets

Introduction

The number of retail farmers' markets in the USA grew from about 340 in 1970 to over 3000 in 2001 and was especially rapid after the passage by the US Congress of Public Law 94-463 (PL 94-463), the Farmer-to-Consumer Direct Marketing Act of 1976 (Brown, 2001). The growth in popularity of farmers' markets has been variously attributed to factors of changing consumer interest and the changing economics of agriculture.

This article catalogs and reviews a large number of reference materials on farmers' markets written since the Second World War. Many of the articles cited in this paper are not well known, including Masters theses, project reports, congressional documents and other narrowly distributed materials. The obscurity of this work is unfortunate as it forms an interesting and informative background for research being undertaken today.

The studies included herein were selected primarily for their discussion of the social and economic impacts of retail farmers' markets. No attempt is made to discuss the many 'How To' handbooks, the literature on legal aspects of direct marketing, or the literature on wholesale farmers' markets, cooperatives, small-volume produce auctions, and farmer sales directly to supermarkets. Some of the neglected works are listed in the USDA farmers' market bibliography (Klotz, 2001).

The literature on farmers' markets and direct marketing is very meager and on critical reading proves somewhat disappointing. While a wealth of quantitative data was collected using PL 94-463 and related funding, in recent years only a few studies of North American farmers' markets are scattered across the literature of economics, horticulture, rural sociology, ethnography, geography and extension. Since the end of PL 94-463 funding, few quantitative studies have been undertaken and the question of how to measure the effects of farmers' markets remains unclear. Recent studies, whether quantitative or qualitative in their approach, tend to share many bibliographic entries, including an alarming proportion of articles from the popular press.

I will start by discussing the methodological problems encountered in the scholarly study of direct marketing. The remainder of the paper focuses on farmers' markets and discusses selected studies of consumers and vendors, economic and social impact, and the use of farmers' markets as research sites. The review sections summarize the findings of numerous studies. Particular studies may be singled out for special mention with others listed for further reference. This approach unavoidably glosses over methodological and theoretical distinctions and minor variance in findings. It is hoped that follow-up articles will offer deeper analysis and discussion of important points.

Methodological Concerns

One reviewer of an earlier draft of this article suggested that quantitative measurement of farmers' markets may prove to be impossible because of the complexity of the interactions that can be found there. While I do not believe that we should abandon quantitative assessments in the study of farmers' markets, there is no question that studying direct marketing is a difficult undertaking. The rapid growth in the number of farmers' markets and their popularity with consumers and producers argues that they must be economically efficient, but Toothman's excellent discussion (Toothman, 1981) of the problems in modeling and reporting direct marketing operations remains valid today. Researchers do not agree as to the definition of direct marketing methods. Differing state regulations on permitted products, in particular meat and dairy products, skew results. Findings are often reported as averages without supporting information to allow deeper analysis. The relative returns using the many different direct market channels is only glimpsed at. Why are farmers' markets successful in a developed market economy where consumers and farmers have many options for buying and selling food?

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We cannot entirely blame lack of funding for the difficulties in quantitative research. The well-funded Census of Agriculture and the work by USDA economists Henderson and Linstrom illustrate some of the difficulties.

The US Census of Agriculture periodically questions farmers about direct marketing. The 1997 Census (USDA, 1997) defined a farm as 'any place from which $1,000 or more of agricultural products [and subsidies] were produced and sold or normally would have been, during the reference year', in theory, counting nearly every farm. However, the Census is based on locally developed lists of farmers and these lists are notoriously inaccurate (Griffith, 2000).

Griffith, using a mathematical analysis, estimated that as many as 22% of the farms in south-western Pennsylvania were missed by the 1997 Census. These farmers would likely be the marginal farmers most likely to use direct marketing channels including farmers' markets. Griffith's finding has not yet been validated by field assessment, but it reconfirms other questions raised over time about the Census process. It also sheds doubt about the validity of Census findings, such as the Gale (1997) report that 48% of direct market sales in the 1992 census (USDA, 1992) came from farms with total agriculture income over $100,000. In a larger context, it casts a very dark shadow over the entire body of literature on US farm location.

The information collected by the Census on direct marketing is felt by many to underestimate returns. Direct marketing is said to have accounted for $404 million in 1997 (Gale, 1997), a number believed by other investigators to fall far below the actual value of direct market sales (unpublished discussion). The Census relies on farmer memory and farmer openness and is thus subject to error (Gale, 1997). The various Census questions related to production expenses are not well suited to an examination of the diverse activities small farms undertake today. The Census does not catagorize sales according to different direct marketing channels, so returns from farmers' markets cannot be determined from Census of Agriculture data. Another problem in using the Census of Agriculture is that direct marketing questions have been asked only infrequently. Thus changes over time can only be approximated.

In the 1970s and early 1980s, USDA researchers Henderson and Linstrom used PL 94-463 funding to explore direct marketing. Henderson and Linstrom contacted farmers in selected states to survey their participation in a broad range of direct marketing methods, including farm stands, farm shops, pick-your-own, retail farmers' markets, house-to-house sales, and direct-to-consumer sales by farmer associations. The results were reported in numerous USDA publications, including Henderson and Linstrom (1980, 1981a, b, 1982a, b), Linstrom (1978), Linstrom and Henderson (1979, 1980) and Linstrom and Wiser (1978).

This research used elaborate and expensive survey methodologies unlikely to be replicated today, yet despite their painstaking efforts, Henderson and Linstrom point out that methodological weaknesses persisted. The studies may have overlooked many small producers, and thus was perhaps biased toward fruit and vegetable growers. Henderson and Linstrom note that farmers tend to understate rather than overstate sal They report that one of their state-level informants had d showing that one farmer from that state 'had greater direct sa of milk than our data showed for the entire state' (Henderson a Linstrom, 1982a, p. 3).

In all eras, differing definitions of direct market and differ reporting conventions make economic comparisons at the st level almost meaningless. Some states permit farms to proc and sell milk and meat directly to consumers. Including th sales in the analysis distorts findings by attributing high incom to a small number of farmers. Some states include marketi cooperatives and the proceeds from farmer wholesale markets their estimates of farmers' market and direct market sales. I recent study, Georgia excluded sales of non-food items such flowers, nursery products, wool and value-added products fro report on direct marketing (USDA and University of Georg 1996). Value adding and agricultural specialty service inco streams are not widely reported.

Another methodological problem is that findings are oft reported as simple averages. The sales revenues from farme markets range from about $50 a day in smaller markets in ru communities to over $15,000 on an occasional day at New Yo City's Greenmarket. The average incomes of very success full-time and part-time farmers, makers of value-added produc cheese makers and flower growers may be very different a disguise differences between diverse types of vendors a markets, and across locations.

If prominent economists Fugita *et al.* (1999) are to believed, until the mid-1990s, there had been no methodology modeling conventions in economics adequate to the task describing the complex interactions between businesses (inclu ing farms) and their surrounding regions. If the methodolog they propose gain wide acceptance, future researchers may fi that methodologies adapted from business management are w suited to the study of farmers' markets. At the very lea farmers' market researchers might adopt the specialized ca study conventions that have been used by business research for the past 20 years. In the mean time, the weaknesses of mu of the quantitative literature on farmers' markets cannot ignored.

Who are the Farmers and Consumers found at Farmers' Markets?

Markets cannot exist without vendors and customers, and successful market satisfies the needs of both. Numerous surve of North American farmers' market vendors and consumers ha been completed since 1970 (as yet no earlier ones have be found); however, these studies provide few surprises or insig into the farmers' market dynamic. Farmers use farmers' mark because they feel that they are the best (or often only) mar channel available to them. Consumers patronize farme markets because they enjoy them and feel that the mark provide high-quality produce at a reasonable price. People w access to farmers' markets enjoy shopping there and think i socially beneficial to do so. People do not shop at markets wh

are inconvenient or of which they have no knowledge (Abel et al., 1999; Anderson et al., 1996; Brenner, 1999; Burns and Johnson, 1996; Capstick, 1982; Cartier, 1994; Curry and Oland, 1998; Estes, 1985; Govindasamy and Nayga, 1996; Jack and Blackburn, 1984a, b; Karim, 1981; Kenyon et al., 1979; Ladzinski et al., 1983; Lev and Stephenson, 1998; Linstrom, 1978; Pyle, 1971; Rural Enterprise, 1987; Swanson and Lewis; 1991; Urban Market Collaborative, Inc. and USDA, 1996; Wynne and Roth, 1997).

Generally the radius of trade (the distance that farmers and vendors will travel) can be considered to be about 32 km (20 miles). Researchers agree that farmers and customers are more likely to travel longer distances to attend better markets or to attend the more scattered markets of rural areas. Govindasamy et al. (1998a) found that a sample of New Jersey farmers travel 2–113 km (1–70 miles) to their farthest market, with a mean of 43 km (27 miles). The range of farthest markets was 8–121 km (5–75 miles), with a mean of 68 km (42 miles). Metcalf (1999) reported that the Dane Country, Wisconsin county farmers' market drew farmers and customers from a radius of 386 km (240 miles). (See also Brooker and Taylor, 1977; Burns and Johnson, 1996; Govindasamy et al., 1998b; Jack and Blackburn, 1984a, b; Leones et al., 1995; Roy and Jordan, 1977; Roy et al., 1978; Schooley et al., 1988; Wynne and Roth, 1997.)

The identification of patrons and potential patrons is important to farmers, market organizers and sponsoring agencies. Consumer surveys, which may be based on attendance counts, exit polls, door-to-door canvasses, postal or telephone questionnaires, are fairly consistent across time and location. A selection of these studies is summarized in Tables 1 and 2. The tables indicate that so few differences have been uncovered across 20 years of studies that the question can be raised as to whether the research was being conducted on the right issues.

Some patrons of farmers' markets choose to buy a large portion of their summertime fresh produce needs from markets. Most researchers surveying customer patronage patterns report high levels of repeat patronage. Stephenson and Lev (1998) found that 46% of the population of two communities in Oregon visited farmers' markets 1–9 times per year and 13% visited more than 10 times. Swanson and Lewis (1991) reported that 43% of urban Alaskans shop at farmers' markets or roadside stands several times per year. Roy and Jordan (1977) reported that white customers in Louisiana averaged 18 visits per year and black customers averaged 24. Yet Rhodus et al. (1994) found that Ohio patrons reported few multiple visits to farmers' markets, preferring instead to visit roadside stands. (See also Estes, 1985; Govindasamy et al., 1998b; Jack and Blackburn, 1984a.)

The most important factor in the composition of the customer base of a farmers' market is location: markets draw primarily from the neighborhoods where they are sited. Most customers at farmers' markets are Caucasian (if race is reported), middle-aged, middle-income or above, well-educated women. The national dietary trend toward greater consumption of fresh fruit and vegetables by the middle-class, is thought to affect patronage of farmers' markets (Capstick, 1982; Cartier, 1994; Connell et al. 1986; Eastwood et al., 1995; Lockeretz, 1987; Roy and Jordan, 1977; Roy et al., 1977; Wynne and Roth, 1997).

It is doubtful, however, that location and product mix alone tell the whole story of consumer demographics. Unfortunately, data pooling or other meta techniques using the results of past research are unlikely to yield answers to sophisticated questions of consumer segmentation because data collection has not been refined enough. Extant studies do not provide profiles or information on political awareness, reading habits, health education, or other personal or cultural factors that might be expected to influence consumer patronage of farmers' markets.

Farmers attending farmers' markets have been surveyed many times, with fairly consistent findings. It is well established that many vendors depend on farmers' markets for significant portions of their agricultural income, but this finding has not yet been integrated into the larger scholarly discussions of multiple income streams in North American agriculture, the social needs of older people, or the larger changes in the characteristics of the labor force which have been seen in the past quarter century (see Anderson et al., 1993; Brooker and Taylor, 1977; Burns and Johnson, 1996; Capstick, 1982; Estes, 1985; Govindasamy et al. 1998a; Roy et al., 1978).

Farmers participating in farmers' markets are more likely to be small-scale farmers. Wann et al. (1948) and Linstrom (1978) suggested that large-scale farmers often find the economics of farmers' markets unfavorable. Yet, today, other farm management patterns exist, made possible by the structure of the modern labor force and changes in current patterns of income earning. The importance of farm size is unclear, in part because too few researchers have linked farm size to other business characteristics. A recent study by Govindasamy et al. (1998a) highlights the complexity of the farm size question. In a survey of 36 New Jersey farmers, the area farmed to support farmers' market sales ranged from 0.08 to 57.7 ha. (0.2–150 acres) with a mean of 11.5 ha (30 acres). Retail sales through all channels were supported by an average of 18.8 ha (49 acres) in production but the range was from 0.4 to 161.5 ha (1–420 acres). Farmers owned land, managed land and rented land for production, and they reported increases and decreases in land area farmed in the past 5 years in different ratios for farmers' market sales and other retail sales categories (see also Capstick, 1982; Degner et al., 1981; Roy et al., 1978).

Many farmers' market vendors are retired from other occupations or are part-time farmers with other sources of household income. Many have arrived at the market by indirect career routes and their non-farming background features largely in the popular press. Ward Sinclair wrote in *The Washington Post* (1990):

> . . . looking around a market [one sees] a carpenter and a construction worker, farming part time, leaning toward becoming full-time farmers; a naval weapons expert selling honey from his bee and sheep operation; two journalists turned into successful bakers; a college-trained anthropologist making it with flowers and vegetables; a television repairman now an expert full-time grower.

Table 1. Characteristics of consumers at farmers' markets (1990–2000).

State	New Jersey	Ohio	Tennessee	Missouri
Researcher (Number of markets surveyed) Number of respondents	Govindasamy et al. (1998b) (21) 303 (Paper survey)	Rhodus et al. (1994) (0) 500 (Telephone survey)	Cartier (1994) (3) 1038 (Paper survey)	Anderson et al. (199 (5) 4120 (Interview)
(Methodology) Demographics of main customer segment	–	29% had shopped at market, 86% female, 50% > age 50	Caucasian, female, college educated, >45 years old	–
Frequency of visits	6% twice weekly; 45% once weekly; 21% once fortnightly; 24% monthly; 5% once/year; 77% patronized more than one market in a year	10% >21 visits/year; 7% 11–20 visits/year; 15% 6–10 visits/year; 8% 4–5 visits/year; 33% 2–3 visits/year; 27% once/year	69% indicated that they plan to visit market at least weekly	62% visited more th 15 times per year— one site 80% visited more than 15 times per year
Reasons for visiting (descending order)	1. Quality 2. Variety 3. Convenience 4. Price	–	Survey asked if markets or supermarkets were better on a variety of characteristics. Markets were consistently rated superior to supermarkets	1. Quality 2. Prices 3. Atmosphere 4. Variety 5. Convenience 6. Help farmers
Amount spent per visit (beware of the effect of inflation across years)	Range: $3–125; mean: $16	–	$13	–
Reasons for not shopping at farmers' markets (descending order) or complaints about the market	1. No market nearby 2. Did not know about them 3. Inconvenient 4. No time 5. Preferred supermarket	–	Varied by location. Negative comments included parking, range of vendors and produce, price and hours	Inconvenient. 90% said they would be willing to shop at a new local farmers' market

Hughes and Mattson (1992) developed a list of 34 skilled and unskilled occupations found among the 185 persons tending market stalls in Kansas farmers' markets. Differences in attitude and expectations between these multi-skilled farmers or between part-time and full-time farmers attending markets are only beginning to be discovered. Differences in their farm management behavior have yet to be examined.

Recently, researchers have begun to go beyond the somewhat simplistic studies of farmers and consumers discussed thus far. Lev and Stephenson (1998), for example, found that more than 10% of Oregon shoppers in two markets said that they did not spend more in the market because they could not carry any more, a finding which calls into doubt earlier work on consumer behavior. Researchers at Rutgers, under the leadership of Ramu Govindasamy, have begun to examine multiple income streams and satisfaction with profit levels among farmers' market vendors. The table of contents of Govindasamy et al. (1998a) may be read as a research agenda for the next decade, with topics including stage of farm development, farm size, employment patterns, ownership patterns, market channel analysis, travel distances, vendor motivation, vendor satisfaction with profits, marketing style, product mix and demographics.

What has been the Economic Impact of Farmers' Markets?

Prior to PL 94-463 few researchers seem to have examined t economic impact of direct marketing or retail farmers' marke The few studies published since 1970 tend to report gr measures without deeper analysis. Few writers analyze da according to the class of market being discussed; wholesale a retail farmers' markets sometimes mingled in the same data se Thus, it is difficult to understand the economic impact that t change in the numbers of farmers' markets, and the increas popularity of direct marketing, has had over time.

Besides the Census of Agriculture, few structured studies the economics of direct marketing have been undertak recently. Burns and Johnson (1996) report estimates of lo economic impact of farmers' markets from several states a counties. These estimates are based on the observations informed individuals, and do not represent the results structured research. Yet, because they are almost the only su estimates available, they are widely quoted.

Burns and Johnson refer to McLaughlin and Perosio (199 for an assertion that 'in 1993, national sales of fruit a

Table 2. Characteristics of consumers at farmers' markets (1980–1990).

State	Pennsylvania	North Carolina	West Virginia	Delaware
Researcher	Connell et al. (1986)	Estes (1985)	Jack and Blackburn (1984a)	Ladzinski et al. (1983)
(Number of markets surveyed) Number of respondents (Methodology)	(0) 400 households (Telephone survey 180 households reported using farmers' markets)	(20) 100 (5 consumers at each market)	(–) About 800 (Paper survey)	(–) 633 (Paper survey)
Demographics of main customer segment (beware of the effect of inflation across years)	58% live in towns 2500–50,000 population; 77% in the area >10 years; 58% <50 years old; 43% >12 years of education; 90% female; 97% Caucasian; 59% income >$20,000 year^{-1}	–	Farmers' markets not disaggregated; gender and ethnicity not reported; 24% retired; 43% >12 years of education; income levels low because of age of patrons	Farmers' markets not disaggregated; gender and ethnicity not reported; 44% >50 years old; 64% >12 years of education; income levels low because of age of patrons
Frequency of visits	32.6% weekly; 16.6% fortnightly; 60.9% monthly	75% said they visited markets at least once per week	>25% of users made 10 or more visits to farmers' markets in 1981	–
Reasons for visiting (descending order)	1. Freshness + not pre-packed 2. Quality 3. Variety 4. Self-select 5. Price 6. Good atmosphere	1. Quality 2. Price	1. Quality 2. Price	1. Quality 2. Price
Amount spent per visit (beware of the effect of inflation across years)	$8–10; >20% spend >$15	$1–12; mode: $3–6	72% spent $5–10 per visit	–
Reasons for not shopping or complaints (descending order)	1. No complaints 2. Too crowded 3. Not clean 4. High prices 5. Poor parking 6. Too far away	Narrow range of products (unclear what is meant); inconvenient location	1. No market nearby 2. Inconvenient 3. Product limitations	Inconvenience; did not know about local markets; lack of toilets

vegetables through direct marketing channels totaled $1.1 billion' (p. 2). When contacted about the source of this estimate, Kristen Park, a colleague of McLaughlin and Perosio, answered that the source of the $1.1 billion figure is an educated guess. Yet this guess, too, is widely quoted.

Similarly, an often-seen estimate is that 3% of the national supply of fresh produce moves through direct marketing channels. My best guess as to the source of this number is a congressional report published by the Comptroller General of the United States (1980). Researchers contacted by email in the course of preparing this paper informally recall that today about 1–2% of the national produce supply is marketed directly. If this number could be substantiated, it would represent a stunningly large amount of product given the manyfold increase in fresh produce sales over the past 20 years.

The largest body of economic research on farmers' markets and direct marketing dates from the late 1970s and early 1980s. Henderson, Linstrom and other writers of the PL 94-463 period present masses of information on farmer participation in direct marketing. As far as can be determined, no comprehensive economic studies of farmers' markets or direct marketing have been undertaken since the end of PL 94-463 funding and, as a result, while the data from this period provide a baseline, there is little to compare it with. Unfortunately, PL 94-463 economic studies are not complemented by satisfactory studies of vendor or consumer behavior and motivation from the same period. Critical linking information from the 1980s has not been found.

The problem of absent national data aside, it is difficult to estimate the impact of farmers' markets and direct marketing even when geographic area and time frame are strictly limited. It remains difficult to calculate net returns to specialty farming. Information on cost of production or wholesale prices for niche crops is often unavailable or suspect. Estimating savings to consumers from farmers' market patronage is beset by the problem of non-equivalency of products and of assigning value to quality factors (see the report on the economics of sustainable

food systems by Integrity Systems Cooperative Co. (1997) as an example of the need to cobble together aged and suspect data in order to make economic statements).

Even with structured studies, extrapolation of the results to a state or to the country as a whole is very inexact. Hughes and Mattson, to approximate gross receipts for farmers' markets in Kansas, multiply the '(number of markets) × (number of vendors) [who responded to their survey] × (number of days participating) by (earnings per market day)' to arrive at a figure of $528,660 (Hughes and Mattson, 1992, p. 8). This estimate may be contrasted to the $3,324,000 reported by the Census of Agriculture for Kansas in 1992 for all direct market outlets, raising a question of what other methods of direct marketing in Kansas account for such a large difference. Similarly, a 1987 New York state survey found that about 25% of the state's non-dairy farms sold products direct, with 51% of these reporting some sales through farmers' markets. Sales direct to consumers totaled $112.3 million, averaging $18,328 per farm (Schooley et al., 1989). These findings may be compared with those of Henderson and Linstrom (1980), who reported $86.3 million in total direct sales in New York state, and the 1992 Census of Agriculture which reported $32 million.

Another approach to estimation of economic returns to farmers' markets is to calculate consumer spending. Burns and Johnson (1996) point to the problem of using consumer data collection to estimate cash flow within a market:

> Some data exist from site-specific studies that asked customers what they spent on a given day and then multiplied the figure by the estimated total number of customers. However, the results of these studies vary widely. The study in Madison, WI found the average customer expenditure was $10. However [in a later study] where customers were interviewed on 4 different days, [the customers] spent an average of $17.90 per visit . . . Those markets with vendors selling mainly vegetables would likely have a lower average than those markets that allow value-added items such as cheeses, herbs, ornaments, baked goods, and other prepared items.

An economic impact commonly attributed to farmers' markets is increased spending in nearby shops by customers attending the market. This spending benefits those businesses and, in theory, generates more tax revenues for local communities. Although local businesses may initially regard a new farmers' market as a threat, businesses are reported to notice an increase in trade on market days. Lev and Stephenson (1998) found that 63% and 38% of the visitors to the Corvallis and Albany, Oregon, farmers' market planned to do other errands in the area that day. The lower rate in the Albany market is partially attributable to that market's early morning hours. Lev and Stephenson calculated that market visitors spend over $11,000 in each of the two surrounding communities on market days. (See also Curry and Oland, 1998; Fisher, 1999; Foster, 1991; Hess, 1974; Wynne and Roth, 1997.)

As yet, research into the economic efficiency of farmers' markets is rare. Many agricultural economists remain content to explain that farmers' markets affect only a localized area and a few households and therefore are of little importance. Ma economists and social science writers on the history of mark development accept without question that improved lon distance trade in out-of-season commodities is a major objecti of a marketing system, and contend that the measure of mark efficiency is cost per unit, and opine that the consumer (re 'voter') is best served when the price of food is lowest (s examples of this discussion in Abbott and Makeham, 199 Andreou, 1977; Ballock and Shell, 1991; Bohannan and Dalto 1962; Cramer et al., 1997; FAO, 1975; Hodder and Ukwu, 196 Paarlberg, 1980). This approach often ignores the food quali and environmental benefits of reducing transport costs, t physical and nutritional waste associated with wholesa markets, and the negative social results of the farm consolidati necessary to support an extended wholesale system.

Pricing of products in farmers' markets is very much mark driven, that is, the seller chooses a price reflecting what t consumer seems willing to pay. Farmers' market prices are, many cases, close to or above supermarket prices for sor products (Blake, 1994). Yet Brucato (1948) and Hess (197 reported that market prices were 35 and 50% of prevailing reta prices in 1943 and 1973, respectively. The change in pri spread does not mean that farmers' markets are in some wa losing efficiency but that direct price comparisons are clum measures.

An interesting and understudied question is that of waste direct marketing. Custom harvest and quick delivery, practiced by many farmer market growers, mean that produc have little time to spoil. Diversified planting schemes and mark channels mean that growers seldom need to destroy a cr during a glut (a farming practice that is not always accounted f in studies of waste; see, for example, Kantor et al., 1997). course, there are added costs involved with custom productio and the economic issue is one of 'unnecessary' waste a associated changes in price and availability.

What are the Social and Political Impacts of Farmers' Markets?

Social and political effects of public markets and marke places have been seen throughout history (Braudel, 1982; Smit 1979, 1980). Smith, in his review of literature on period markets, notes that determining whether economic or no economic factors predominate in an individual's decision attend a particular market is 'extraordinarily difficult' (1980, 2). There is no doubt that social interaction is an important pa of the decision of modern farmers and consumers to atte farmers' markets. This being said, there have been fe structured studies of the social implications of contempora farmers' markets.

Curry and Oland (1998) writing of Prince George, Briti Columbia, comment on the economic multiplier effect farmers' markets: markets increase the number of jobs a build new businesses; markets strengthen and diversify regio agriculture and increase farm profitability; and farmers' mark serve as business incubators. The Granville Island Market Vancouver creates 3.2 full-time and 4.3 part-time jobs p

vendor. Farmers' markets also generate secondary employment opportunities in supporting businesses. Curry and Oland report a steady increase in property values in the market district and increased tax revenues as benefits of modern farmers' markets.

ECOnomics Institute (1999), Hilchey et al. (1995), Lyson et al. (1995) and Morales et al. (1995) explored the relationship between public markets (including farmers' markets), the informal economy and the business incubation function of markets, and concluded that markets are beneficial. Markets help enterprises progress from personal interest to hobby to business. Low barriers to entry and a warm social atmosphere encourage entrepreneurial activity and experimentation with new ideas and products. Cluster effects force and support the development of business management skills. Hilchey et al. (1995) noted that farmers' markets help circulate money within a local community which might otherwise be spent on imported goods. Markets draw tourists, they provide supplemental income to participants and hired workers, and they can teach business skills to young entrepreneurs.

Hilchey et al. (1995, p. 9) noted that farmers' markets 'by helping farmers stay in business . . . directly contribute to the preservation of open space, and the maintenance of the rural character of the land' (1995, p. 9). The evidence for this contention, which is made by others, including Curry and Oland (1998) and Gale (1997), seems to be the confirmation by interviewed farmers that they rely on farmers' markets to stay in business. Studies linking farmers' markets to changes in land-use patterns have not been found.

A few ethnographers and psychologists have investigated farmers' markets and flea markets. Sherry and his colleagues have combined business, anthropology and ethnographic paradigms in studies of informal marketing in recent publications (Belk et al., 1988; McGrath et al., 1993; Sherry, 1988, 1990a, b, 1998). This research brings modern research tools and a deeper sensibility to the observation of consumers and vendors in a market, and re-examines markets in the light of modern interest in the relationship between vendor and consumer and the relationship between economic and non-economic functions of the informal market. Earlier, psychologist Robert Sommer and his colleagues compared supermarkets and farmers' markets and found that farmers' markets were more friendly, personal, rural, smaller and 'happier' than supermarkets (Sommer and Wing, 1980; Sommer et al., 1981) and that there were regional and seasonal differences in produce consumption at supermarkets and farmers' markets (Fjeld and Sommer, 1982). The literature on regional food security on occasion links subscription sales, Community Supported Agriculture (CSA), community gardens and farmers' markets as components of community food systems (see, for example, Curry and Oland, 1998; Newman, 1997).

Unfortunately, some social science studies are presented in ways not immediately useful to farmers or market masters, who are more likely to be looking for effective market management tips than semiotics. Highly jargon-laden social science papers may baffle growers seeking hints on improving their market. Farmers and market masters are unlikely to read the journals in which some of these studies have been published. In an attempt to assist in the cataloging of these various studies, USDA maintains an internet site with links to scholarly reports.

The role farmers' markets have played in the development of markets for exotic and organic foods is acknowledged primarily by food writers but does not seem to have been confirmed by research. Farmers' markets are thought to represent important testing grounds for new products and new technologies. For some products, most notably extremely perishable products, such as edible flowers, farmers' markets and other direct farmer-to-chef links remain virtually the only source of supply (Brenner, 1999; Egan, 1999; Kaminsky, 1999).

The link between farmers' markets and recent trends in horticulture research cannot be separated from the influence of the environmental movement and the increased interest in good food of all sorts. There does not seem to be research linking widened availability of seeds and seedlings for horticulture crops to an increase in market gardening supported by farmers' markets, but the parallels in growth make for interesting conjecture. Similarly, the organic food industry has grown in tandem with farmers' markets. The relationship between farmers' markets and the organic movement seems to be largely undocumented [the absence of a discussion of this connection in Gates (1996) is noted]. One might argue that without an early commercial outlet for these products, producers and consumers would have been frustrated in their efforts to connect. Farmers' markets were certainly the most visible source of organic products until quite recently and they still remain one of the best sources of culinary exotica.

Farmers' markets as research sites

Farmers' markets have also been used as sampling frames for investigations of a range of topics. Recent studies have used farmers' market consumers to examine:

- attitudes toward chemical use in agriculture and produce quality (Anderson et al., 1996; Govindasamy et al., 1997; Kitasei, 1992; Lev and Stephenson, 1998; Sommer et al., 1982; Swanson and Lewis, 1991);
- attitudes toward sustainable agriculture (Stephenson and Lev, 1998);
- attitudes toward food safety (Preston et al., 1998); and
- waste food recovery in the context of farmers' markets (Price and Harris, 1998).

In a particularly disturbing report, a farmers' market in Canada was found to be a retail outlet for contaminated cheese (Preston et al., 1998).

Conclusion

The extant research literature supports the notion that economic factors clearly motivate most farmers and some consumers to attend contemporary farmers' markets. Although researchers acknowledge that various non-economic factors are also very important, studies into the social and non-economic impacts of farmers' markets remain uncommon. Overall, the conceptual and methodological questions of how to explore the richness of direct marketing and identify the effects of mixed

marketing channels and a diverse customer base remain unanswered. The literature to date only hints at the impact of direct marketing and farmers' markets on farmer income, farm production patterns, land use, consumer diets, changes in consumer spending patterns, changes in consumer, farmer and community attitudes, the economic or social impact of markets on communities and the far-reaching implications of direct marketing on the food system.

There are conceptual and methodological hurdles to be overcome if we are to develop a body of valid and reliable research on agricultural direct marketing. These are exciting times for students of farmers' markets.

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Sheep stocking under traditional and improved grazing systems in the cereal–sheep system of Castile–La Mancha (south-central Spain)

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Abstract. *Land-based systems of low stocking rate are usually associated with low environmental concerns. However, we hypothesized that traditional unrestructured grazing systems may represent more environmental costs than benefits. Community-based research work was conducted in the 1990s in the cereal–sheep system of Castile–La Mancha, with the objective of assessing the typology of the system, including the grazing structures and social groups involved in grazing management. Results showed that traditional management represented a heterogeneous spatio-temporal distribution of grazing at the regional level, with high variability at the local level. Occasional overgrazing may occur, but a trend towards fewer grazing-days with correspondingly more indoor feeding and widespread underuse of grazing resources was more apparent. Proposals to improve the grazing system reached a high degree of consensus among farmers, but the two social groups (cultivators and landless pastoralists) showed divergent views in some important management issues. The imbalance in group numbers indicated that collective action is difficult to achieve. Implementation of improved grazing practices would require a policy intervention based on the disentangled constraints and consensus among interested farmers.*

Key words: agro-pastoral systems, environmental implications, grazing management, landless tenure, Mediterranean agriculture

Introduction

Sheep (*Ovis aries*) grazing is a major value-added agricultural operation in semi-arid areas. Sheep utilize natural pastures and shrub vegetation in extensive systems, and agricultural field residues and supplementary forage in agro-pastoral mixed-farming systems.

In most countries, however, the environmental implications of sheep grazing are a matter of controversy. In developed countries, sheep grazing needs to clear its image as a sound ecological operation (Caballero, 1999). Whether sheep grazing represents an environmental hazard is more a matter of the degree of intensification or grazing practices than of the influence of the animals *per se* (Parker, 1990). Conventional wisdom may identify low-input extensive grazing systems (traditional) with low environmental impact, under the assumption that the share of appropriate to available biomass is low and may sustain the grazing resource in the long term (Steinfeld et al., 1998). This utilization coefficient can be a useful grazing indicator in on-farm field-station experiments (Hodgson, 1990), but extensive grazing systems represent large areas of pastoral agriculture relative to the size of the business where free-range sheep still survive intact. Extensive grazing systems are often complex elaborations of the human societies to which they belong, with many structural, legal and environmental implications that can, if only partially, be captured under a wider perspective.

The European Union (EU) supports traditional grazing systems under the assumption that direct payment schemes may sustain these systems and that they may derive environmental benefits. In fact, 80% of sheep farmers receiving premiums are located in the Less Favored Areas (LFA), where European farmland of the highest importance for nature conservation is found (Baldock, 1998; Brouwer et al., 1997). However, our research will argue that unrestructured grazing systems, unadjusted to present economic and social realities (traditional systems), will not be sustained with current support schemes, and that these traditional systems may be the source of more environmental concern than assets.

Environmental EU regulation is becoming a policy instrument to meet the environmental function of the European Model of Agriculture (EMU). The Common Rules Regulation (1259/1999) established a general baseline (red line) on all member states (legislation) and specific agri-environmental measures under the Rural Development Regulation (1257/1999) to promote 'good farming practices' (blue line). A higher level of environmental performance (green line) can be reached if farmers provide environmental benefits, for which they are eligible for environmental payments (Petersen and Baldock,

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2000). The main flaw of these policy instruments is that policy measures can only be devised after gaining proper knowledge of the main characteristics and constraints of extensive sheep-grazing systems. However, a typology appraisal of these systems at the EU scale is lacking.

Paying farmers to initiate positive management also requires a modeling response of farmers to a set of guidelines. Thus, a typology analysis of policy relevance should undergo two steps. First, recording regional systems and, second, assessing farmers' responses to a set of proposals to improve the systems. The main objectives of the present research were to assess the environmental performance of a traditional grazing system (the cereal–sheep mixed production system of Castile–La Mancha, south-central Spain) and the modeling response of farmers to an improved set of grazing practices.

Material and Methods

The traditional mixed-farming system

Castile–La Mancha is the third largest region within the EU and occupies the southern Castilian Plain in Spain (mean elevation 600 m). The Tajo and Guadiana rivers drain the plain, which has a mean regional rainfall of 450 mm and a Mediterranean–continental-type climate. The total agricultural area (TAL) in 1997 was 7.6×10^6 ha, 70% of which is arable land (AL), mostly rainfed (95%). Winter cereals, annual legumes, fallow, sunflower (*Helianthus annuus* L.), olives (*Olea europea* L.) and vineyards occupy 42, 6, 20, 8, 9 and 15% of rainfed arable land (RAL).

Main grazing feed resources included non-arable land (natural pasture, shrub–steppe vegetation and Mediterranean forest), mostly located in the mountainous fringes of the plain, and agro-pastoral sources (cereal stubble, legumes, sunflower and fallow), mostly located in the central part. Patches of olives, vineyards and irrigated land are by law excluded from grazing use for pastoralists who rent the grazing allotments. The main breed within the regional flock (3.2×10^6 breeding ewes) is the Manchega dairy sheep. Milk-oriented flocks are dominant in the plain and meat-oriented flocks in the foothills and mountainous areas.

Castile–La Mancha is divided into five administrative provinces (Albacete, Ciudad Real, Cuenca, Guadalajara and Toledo), 15 counties and 916 municipalities. In most of the counties, except in those of the western part and mountainous areas, the mean landholding is less than 10 ha and property is frequently split into non-adjacent parcels. Under these circumstances, cultivators (throughout the paper 'cultivators' refer to farmers who primarily produce crops) cannot maintain their own sizeable flock. Within municipalities, pasture resources are grouped to form grazing allotments (*polígonos de pastos* in Spanish). Under this basic structure of the grazing system, the cereal and sheep operations are carried out on the same land. Two social groups are involved in grazing management: cultivators who own the grazing resources, and pastoralists who own the flocks, the majority of the latter group being landless.

The current legal framework regulating grazing manageme distinguishes three types of resources: grazing land rented landless pastoralists (*polígonos parcelarios*); grazing land large holdings segregated from grazing rights transfer (*polígon segregados o independientes*); and patches of cropland withi the *polígonos parcelarios* where grazing is prohibited by la (olives, vineyards and irrigated land). This grazing structu shows characteristics of agro-pastoral and extensive systems. relies chiefly on agricultural residues for feed, but the small siz of the business contrasts with large and unfenced *polígon* (Steinfeld et al., 1998).

The structure of the traditional grazing system

Two surveys were conducted at the municipality level wit local advisory staff as respondents. Local extension agents wer selected because of their first-hand knowledge of the system, an because they maintained agricultural records and balanced view of relationships between cultivators and pastoralist Respondents were selected randomly within provinces an counties across the region. The first survey was conducted i 1990. Eighty questionnaires were sent covering 916 munic palities, and 62 valid responses were received. This surve represented the situation of the grazing system in 1989. Th second survey was conducted in 1998, with 160 questionnaire sent and 152 received. This survey represented the grazin structure in 1997. In both cases, municipalities were selecte randomly within provinces and counties. In the second survey the sample size was duplicated to get a more balance representation of counties. In the two processes, less than 5 of the originally selected municipalities were changed becaus they were occasionally understaffed or lacked appropriat records. Between the two surveys, a major reform of th Common Agricultural Policy (CAP) subsidy scheme (McSarr reform of 1992) occurred, and its potential influence on th grazing system was assessed.

In the first part of the questionnaire, responses on the structu of the grazing system were elicited, including distribution of th agricultural land regarding its legal use as grazing categor (*polígonos parcelarios*, *polígonos segregados* and cropland non-grazing use), number and size of the *polígonos*, and numbe of small owners receiving a grazing fee within the *polígon parcelarios*. The main objectives were to assess the distributio of stocking at the regional and province levels and changes in th grazing structure of the system.

In the second part of the questionnaire, local staff wer surveyed on some indicators of environmental awareness, i.e manure management, spatio-temporal distribution of grazin within the *polígonos* (number of potential and actual grazing days in an average year), compliance of actual stocking wi stocking regulated in the local ordinances (base-stocking), an location of the sheepfolds (either in the villages or in the grazin fields). In the 1998 questionnaire, local staff were requested consult with local pastoralists on these issues and submit the comments (some 20% of the returned questionnaires containe at least one comment).

Quantitative responses were matriced by municipality, and regional, provincial and county means were calculated. Statistical distribution was represented by the standard deviation of sample means. Non-sampling errors were minimized by a validation process of iterations based on the Delphi technique (Linstone and Turoff, 1975; Marton, 1988). The whole matrix of quantitative data was sent to local agents. In the first iteration, some 5% of respondents introduced at least one correction of their data. In the second iteration, all data were validated. After the validation process, distribution statistics were calculated using the BMDP software (BMDP, 1992).

In 1990, digitalized maps from the Regional Cadastre were unavailable in Castile–La Mancha, and only a few local agents used their own drafted maps, showing the limits of the *polígonos*, but not the patches of grazing resources and non-grazing land. In 1998, the Regional Cadastre had digitalized at least one-third of the municipalities, although these maps were not in use as a grazing management tool. Currently, we are in the process of adapting these maps as a grazing management tool for assistance of the Comisiones Locales de Pastos (Local Grazing Commissions). For this research, however, the main sources of information for local agents were yearly renting accounts of grazing land distribution and the records of parcels and small owner cultivators receiving a grazing fee.

The modeling response of farmers to improved grazing practices

Overhauling of the traditional grazing system, with the objective of enhancing environmental performance, included the responses of farmers to a set of improved practices. This normative step had two main objectives. The first was to provide policy-makers not only with empirical evidence of environmental performance, but also with the reaction of farmers to potential regulation. The second goal was to assess, by a normative examination, which of the proposals laid out by the research team were ones that farmers would be willing to accept, and which were those where differences would exist, but on which a compromise was possible between cultivators and pastoralists. This set of proposals was devised by consensus within the research team and consultation with local agents, after collating and analyzing the structural data of the traditional grazing system. At the end of 1998, the proposal questionnaire was sent to collaborative farmers selected in the second survey. These agents were requested to contact at least one collaborative farmer within each municipality, explain the objectives of the survey, and to submit a copy of the proposal questionnaire. For this phase, farmers were selected as respondents because of the search for individually related and direct views.

The questionnaire encompassed 64 proposals of structural, environmental or social character. For the purpose of this research, we selected the response of farmers to nine proposals clearly related with the management of the grazing system and its environmental consequences. There were 77 collaborative farmers (48% rate of response), comprising 33 cultivators, 23 cultivators–pastoralists and 21 landless pastoralists. Two main objectives were to: (1) assess differences of views between cultivators and pastoralists and (2) determine whether regulatory measures can be applied to the whole region (degree of consensus for specific proposals).

Farmers' choices on each proposal were recorded on a five-point Likert-type scale (Babbie, 1973) ranging from 1 (strongly agree) to 5 (strongly disagree), with point 3 indicating undecided. This rating allowed for calculating the statistical distribution of responses (mean ± SD) and variance analysis (three level categories of farmers and five provinces as factors of variation). The 1D program for distribution statistic and the 2V program for analysis of variance of the BMDP software package were used (BMDP, 1992).

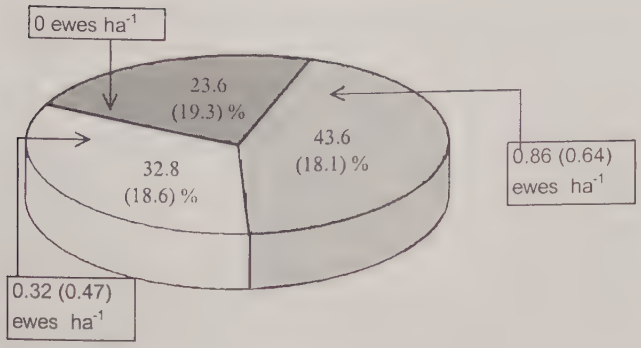
Results and Discussion

Structure of the traditional grazing system

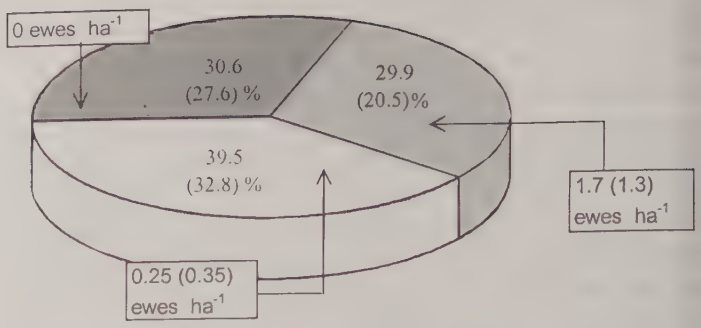
Distribution of the TAL in 1997 by grazing land categories is presented in Figure 1. In two provinces (Cuenca and Guadalajara), the proportion of grazing land under the rented regime (*polígonos parcelarios*) was much higher than under the non-renting regime (*polígonos segregados*). In the other three provinces (Albacete, Ciudad Real and Toledo) the two categories were more evenly distributed. In these three latter provinces, higher proportions of non-grazing, cropping land were found; patches of olive orchards, vineyards and irrigated land are frequently interspersed within the *polígonos*, making it difficult for sheep grazing.

There were large variations of stocking density within legal regimes across the five provinces, and within provinces between legal regimes. Stocking rate was always higher in the *polígonos parcelarios* than in the *polígonos segregados*. The regional mean stocking density in 1997 was 0.42 ± 0.30 ewes ha^{-1}, but stocking in the *polígonos parcelarios* (0.92 ± 0.69 ewes ha^{-1}) was six times higher than in the *polígonos segregados* (0.15 ± 0.26 ewes ha^{-1}). In fact, the 48% of TAL as grazing land under the grazing rights transfer regime (*polígonos parcelarios*) supports 86% of sheep flocks, while the 30% of TAL as grazing land under the non-renting regime (*polígonos segregados*) only supports 14% of sheep flocks, although of larger size (mean of 280 ewes per flock versus 420 ewes per flock).

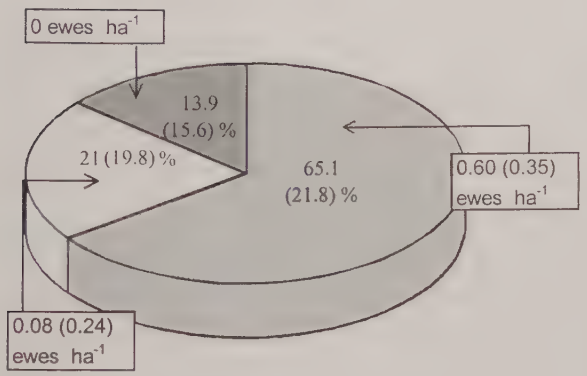
The current legal framework discriminates small- and large-holding cultivators regarding the transference of grazing rights. The first group does not have the opportunity to link grazing rights to land property (grazing rights in the public domain) as does the latter group. The current grazing regulations assume that large landowners may maintain a sizeable flock, but our results showed that this group is largely uninterested in maintaining a mixed-farming operation. In fact, the most frequent value (median) of stocking in the *polígonos segregados* was zero, and the distribution statistic was asymmetrical, illustrating large variations between individual observations (municipalities). Under the current regime, large areas of grazing land are underused and regional stocking of sheep is concentrated in the rented land. It is apparent that, if a more homogeneous spatial distribution of stocking is sought, the segregation of grazing rights transfer awarded to large land-



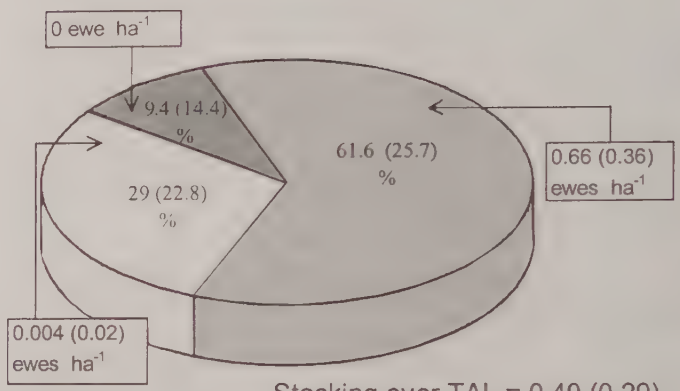
Stocking over TAL = 0.44 (0.33)
Albacete (n=30)



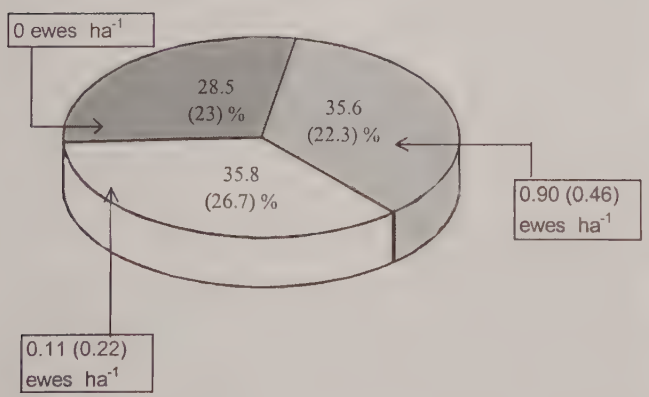
Stocking over TAL = 0.57 (0.44)
Ciudad Real (n=28)



STOCKING over TAL = 0.36 (0.19)
Cuenca (n=37)



Stocking over TAL = 0.40 (0.29)
Guadalajara (n=25)



Stocking over TAL = 0.32 (0.22)
Toledo (n=32)

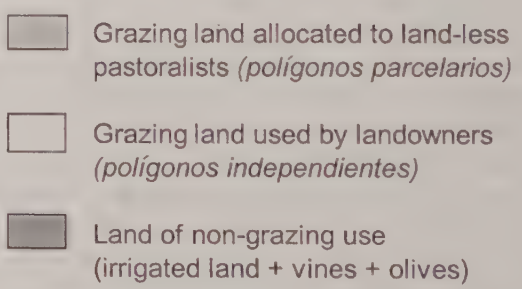

Grazing land allocated to land-less pastoralists (polígonos parcelarios)
Grazing land used by landowners (polígonos independientes)
Land of non-grazing use (irrigated land + vines + olives)

Figure 1. Castile–La Mancha's land share by grazing rights allocation (%) and corresponding sheep stocking rates (ewes ha^{-1}), 199 Sample (*n*) of 152 from 916 municipalities. SD in parentheses; TAL, total agricultural land.

owners should be linked to the maintenance of their own flocks or to a rental contract with a particular landless pastoralist.

Local agents were consulted on the changes occurring in grazing-land categories and flock size in the past 30 years. In 1970, landless pastoralists and cultivators–pastoralists eac owned 45% of the flocks, and the mean flock size was 15 breeding ewes. In 1985, the situation started to change: the firs group owned 49% of the flocks and the second 39%, with a mea

flock size of 220 breeding ewes. Since 1985, the rate of change increased, and in 1997 the mean flock size was 320 breeding ewes, and landless pastoralists owned 77% of the flocks (maintained only on rented land), cultivators–pastoralists owned 9% of the flocks (maintained on owned plus rented land), and large landowners maintained 14% of the flocks. Flock density changed from 2.3 flocks per 1000 ha of TAL in 1970 to 1.98 in 1985, and to 1.33 in 1997. Local agents' comments indicated that many small owner–cultivators, who maintained small flocks for family consumption and additional income, abandoned the sheep operation and farmed only as cultivators, lured by the subsidies awarded to arable land, after Spanish entry to the EU in 1986. These results also suggested that the social structure of the grazing system started to change well before the main revamping of the CAP (McSarry reform of 1992) and thus, social changes seem to be related more to the general improvement of the Spanish economic scenario than to the vagaries of the CAP.

Management implications and environmental concerns

The regional flock size changed little between 1989 and 1997. Official records (M° de Agricultura, 1997) even showed a slightly increasing trend after the McSarry CAP reform (from price support to a per-head payment scheme). However, our data indicated that large areas of grazing land are underused, especially in the Cuenca and Guadalajara provinces. In four of the most hilly and remote counties of these provinces, the mean current number of ewes decreased to 60% of the 1970 level, and 90% of the villages suffered a large depopulation in the same period (INE, 1998). In these areas, where non-arable land is dominant, undergrazing resulted in a loss of natural pasture to shrubby invaders that may decrease biodiversity and increase the risk of forest fires (Gomez Sal and Rodriguez, 1998; Milchunas and Lauenrot, 1993).

The main changes in grazing practices between 1989 and 1997 are shown in Table 1. At the regional level, the production objective is almost evenly distributed between milk- and meat-oriented flocks. Milk-oriented flocks are dominant in the plain and meat-oriented flocks in the foothills and mountain areas. Milk-oriented flocks are dominant in Ciudad Real and Toledo and meat-oriented flocks in Guadalajara. In the provinces of Albacete and Cuenca the dominant objective is linked to specific counties. The production objective may influence some productive practices and environmental concerns. Meat-oriented flocks are generally larger than milk-oriented flocks and are more frequently sheltered on the grazing fields. Milk-oriented flocks are more labor intensive and of greater environmental concern, as most of them are moved on grazing-days from the *polígonos* to sheepfolds near the villages, for sheltering and milking. Few of these flocks are provided with milking facilities (Table 1).

The location of the sheepfold was an important factor for grazing management. Moving the flocks on grazing-days from sheepfolds near the villages to distant parcels requires considerable labor and is an energy-inefficient operation because a sizeable proportion of the sheep's energy resources is redistributed from milk production to locomotion. Grazing resources are seasonal and generally of low quality, but few energy balances under grazing conditions have been reported in this area. Caballero et al. (1992) indicated that Manchega ewes grazing cereal stubble for two months barely meet the energy requirements for maintenance in the first 15 weeks of gestation. Results of this research indicated that the mean number of actual grazing-days is lower than the number potentially available, and is showing a decreasing trend (Table 1).

Table 1. Main changes of grazing practices in the cereal–sheep system of Castile–La Mancha, comparing 1989 and 1997.

Item	1989	1997
Production objective (% of milk-oriented flocks)[1]	55	45
Location of the sheepfold (%)		
in the village or near the village	56 ± 38	52 ± 37
in the grazing fields	44 ± 38	48 ± 37
Potential grazing (days)	200 ± 25	190 ± 37
Actual grazing (days)	150 ± 30	110 ± 60
Proportion of dairy flocks with milking facilities (%)	12 ± 8	18 ± 11
Proportion of flocks under the landless regime (%)	49 ± 33	77 ± 27

[1] The rest (to 100%) are meat-oriented flocks.

Most comments by local agents on this issue suggested that dairy sheep farmers tend to increase indoor feeding and correspondingly decrease grazing-days, especially for the high-requirements lot (lactating ewes). This trend may have environmental and management implications. Stocking derived from the available grazing land of a particular *polígono* and corresponding size of the grazing flock may not represent the actual distribution of stocking by grazing resources and sheep lot. Additionally, while the number and size of the flocks have changed recently, the distribution of grazing lots has not. Grazing laws are out of date and institutionally unenforced. Distribution of grazing land among pastoralists by consensus is widespread. Under these circumstances, real stocking on particular *polígonos* is difficult to assess, and responsibilities for occasional poor grazing management difficult to attribute to particular pastoralists.

The traditional extensive sheep operation was essentially linked to the use of grazing resources by the indigenous Manchega breed. Changes and trends observed in management practices in recent years represented a risk to the identity of regional products, with implications for the agri-food industry. If feeding practices become progressively unrelated to soil resources, and more productive foreign breeds under indoor feeding are used (Molina et al., 2001), the identity of regional cheese and meat will be jeopardized.

Large flocks and uneven distribution of grazing-days within the *polígonos* may contribute to occasional overgrazing within a particular *polígono* and disruptions to cropping land that is not for grazing. The grazing structure of the *polígonos* has not changed according to new social and economic realities and

thus, traditional grazing practices are the source of more economic and environmental concern than benefits.

An additional environmental concern is derived from the traditional management of manure from sheepfolds located in or near villages (some 50% of total barns or shelters). In warm climates and on low organic-matter soils, such as those that dominate in the Castilian Plain, it is important to apply well-composted manure to the arable land. Although data are lacking, most comments by local staff on the issue of manure management suggested that little composting is done and manure accumulations are left uncovered and unprotected from leaching in the vicinity of sheepfolds until pastoralists agree on land disposal with particular cultivators. Barn manure is usually removed during the spring, but manure heaps may be left exposed to spring rainfall and high summer temperatures until disposal by interested cultivators during the following autumn. The manure is not properly composted or otherwise managed to avoid potential environmental hazards such as leaching of nutrients to nearby aquifers or surface waters.

Compliance with grazing regulations

A clearer picture at the regional level emerged when quantitative data recorded by local staff were compared to stocking rates stated in local regulations, noting that these are rarely enforced and date back to the 1950s and 1960s. The local regulations still in force in 1997, stated a base-stocking and a base-flock size (Table 2), allowing designation of trade-off limit between *polígonos parcelarios* and *polígonos segregados*. By dividing the base-flock size by the base-stocking rate, large landowners may apply for segregation of grazing rights transfer to landless pastoralists. The mean limit is 230 ha in Albacete, Ciudad Real and Guadalajara, but 460 ha in Cuenca and only 170 ha in the Toledo province.

Our results showed large variations and lower compliance in the base-flock size and low variations and greater adjustment to regulation in the base-stocking rate. It is apparent that the base-flock size is outdated regarding the current mean flock size. These data, however, suggest that if actual size was considered, the limit for segregation would be higher, and large areas of available but unused grazing land would fall within the transfer regime. This potential provision would imply a more homogeneous spatial distribution of the regional flocks between th two types of *polígonos*.

The base-stocking in *polígonos parcelarios* was wide unenforced. Actual stocking in most provinces, except Guadalajara, was greater than base-stocking. In Cuenca an Guadalajara, lower actual stocking was a consequence of high proportion of grazing land under renting. The opposite occurre in the Ciudad Real and Toledo provinces. Here, more parce under olive orchards, vineyards and irrigation have decreased th available grazing land within the *polígonos parcelarios* in th past 30 years.

Although base-stocking at the regional level cannot be sustaine on proper scientific evidence, it is clear that the range of bas stocking (0.5–1 ewes ha^{-1}) may represent a consensus of sustainab use of grazing resources for many years. A review of availability barley (*Hordeum vulgare* L.) stubble in three semi-arid area of Spain estimated a mean of 200 kg ha^{-1} and 1500 kg ha^{-1} unharvested grain and straw, respectively (Correal and Sotomayo 1998). However, after ewes have consumed the available grain an selected the proportion of straw of highest quality (25–30% grazing cannot be continued without ewes losing live weight an condition score (Caballero et al., 1992). A proportion of unharveste grain is buried by trampling, and a regrowth of cereal an adventitious grasses and weeds (*ricial* in Spanish) may occur wit early autumn rainfall. This extends the cereal stubble grazing seas provided that the cultivators are cooperative and delay plowing.

Reported and observed data may illustrate two main point First, the current stocking rate on the *polígonos parcelarios* somewhat higher than base-stocking, but we cannot label overgrazing without assessing the spatio-temporal distribution grazing. Secondly, the main stocking problem in these semi-ari areas is not due to lack of resources but to seasonality. In Spai as well as in similar cereal–sheep systems of the Mediterranea area (Jones, 1992; Thomson, 1987), a feeding strategy needs t be devised for non-grazing days. The extent to which th strategy can meet the objective is a good indicator of integrate systems (Caballero, 1993). Results of this paper show a region annual mean of 200 potential grazing-days and thus, 165 no grazing days. A mass balance estimated that the curre hectarage of forage legume would only meet about 30% of th current non-season grazing-days at the current stocking rate. A additional trade-off of 15% of the fallow hectarage to forag

Table 2. Regulated versus actual sheep flock size and stocking, and regulated grazing fees in the cereal–sheep system of Castile–L Mancha (1997).

Province	N^1	Base-flock size (no. of ewes)	Base-stocking[2] (ewes ha^{-1})	Actual flock size (no. of ewes)	Actual stocking (ewes ha^{-1})	Grazing fee (pts ha^{-1})
Albacete	31	130 ± 32	0.55 ± 0.24	218 ± 81	0.86 ± 0.63	475 ± 81
Ciudad Real	23	145 ± 140	0.63 ± 0.20	300 ± 150	1.65 ± 1.24	664 ± 152
Cuenca	37	183 ± 181	0.40 ± 0.24	297 ± 190	0.60 ± 0.35	100 ± 13
Guadalajara	25	187 ± 44	0.81 ± 0.19	356 ± 117	0.66 ± 0.35	108 ± 41
Toledo	29	150	0.89 ± 0.20	283 ± 136	0.90 ± 0.46	474 ± 137

[1] Number of municipalities surveyed.
[2] Stocking on *polígonos parcelarios*. Mean regional stocking in *polígonos segregados* is 0.15 ± 0.20 ewes ha^{-1}.
[3] Grazing fees fixed by the Provincial Grazing Commissions, 1 euro = 166.326 pts (pesetas).

legumes would meet the forage deficit. This is only a regional analysis, but the high variation of resource distribution between provinces and counties, and even within municipalities, makes it advisable to address this issue at the level of grazing units (*polígonos*). Meeting the forage deficit with common vetch (*Vicia sativa* L.) hay is one of the best regulatory strategies of stocking, as it may provide economic and environmental benefits derived from the incorporation of legumes into the crop rotation (Caballero, 1993, 2001; ICARDA, 1998; Lacasta, 1995; Papastylianou, 1999; Power, 1987).

Grazing fees were regulated, within a limited scope, by the Provincial Grazing Commissions (Comisiones Provinciales de Pastos). This is the reason for the lower variation observed within than between provinces (Table 2), and the larger variation observed between municipalities of different provinces (see Table 4). These prices were fixed without any relation to resource quality. Contiguous counties of two provinces may have similar grazing resources but quite different prices, as occurred in La Mancha in the Toledo and Cuenca provinces. Within the provincial range, each Local Grazing Commission established the price for the corresponding municipality, but even within each municipality, the quality of the different *polígonos* may vary greatly. Grazing fees are thus enforced but fixed and unrelated to the quality of grazing resources.

Response of farmers to improved grazing practices

After assessing the main environmental concerns derived from traditional grazing practices (poor spatio-temporal distribution of grazing and manure management hazards), a set of proposed reforms was drafted by consensus within the research team and consultation with local staff. The proposals were submitted for consideration to collaborative farmers (cultivators and pastoralists). The set of proposals included structural, environmental and social issues. Farmers' consensus was rated by the cumulative choices of agreement (strongly agree plus agree), indicating whether the response differs significantly between cultivators and pastoralists (Table 3).

A program to favor the accessibility to grazing land and implementing the grazing infrastructure (i.e., sheepfolds, milking facilities, water points, fences, composting facilities, barns or shelters for hay and straw) within the leased *polígonos* reached a very high level of regional consensus without disagreement between cultivators and pastoralist (proposals A_1, A_2, and A_3 in Table 3). The first social group (cultivators) relies on these proposals as a way of lessening the disturbances caused by the herding of flocks, and of obtaining a supply of better-quality manure. The main reason why the second group (pastoralists) favored the proposal was to improve the harsh working conditions of traditional practices. General environmental benefits derived from this program may include improved grazing distribution (facilitating accessibility to grazing resources), improved management and disposal of manure within the leased *polígonos*, and better access to property rights of small plots within the *polígonos*, where landless pastoralists can build the grazing infrastructures and establish plots for complementary forage legume cultivation.

The legal prescription of linking grazing rights to land property in large but not in small holdings motivated the uneven

Table 3. Farmers' reactions to the proposal of reform (improved grazing practices) in the cereal–sheep system of Castile–La Mancha, 1998 ($n = 77$).

Proposal	Conclusion[1] (%)	Significance[2]
A. Structural		
A_1. Landless pastoralists should be favored in a small land redistribution program to acquire some plots within the rented *polígono*	89	NS
A_2. This latter program should also contemplate financial support to landless pastoralists to build the grazing infrastructure on acquired plots	88	NS
A_3. Those landless pastoralists accomplishing the two latter steps should be entitled to a segregation of grazing rights as long as they maintain the grazing operation in the rented *polígono*	85	NS
A_4. Grazing land of largeholdings (*polígonos segregados*) not actually maintaining a flock should revert to the renting regime	79	NS
A_5. The best way to meet the forage deficit is by favoring a hectarage increase of rainfed forage legumes	83	NS
B. Environmental		
B_1. Improved grazing practices in the agro-pastoral system may derive environmental benefits (organic matter and nutrient cycling, weedy plant check, increasing legumes hectarage, better grazing distribution and compatibility with small game)	87	NS
B_2. Even improved grazing practices may cause environmental hazards [disturbance of cultivation practices, soil compaction, damage to farm structures, grazing on land in production (olives, vineyards)]	42	$P < 0.001$
C. Social		
C_1. Grazing rights should be linked to land property and removed from the public domain	53	$P < 0.001$
C_2. Lack of a legal and institutional framework is hindering grazing management	90	NS

[1] Aggregate response of farmers (strongly agree plus agree). The other three alternatives were: undecided, disagree and strongly disagree from a five-point Likert-type scale.

[2] Significance of response between cultivators and pastoralists. NS = not significant.

Table 4. Hunting and grazing fees and support to afforestation in eight municipalities of Castile–La Mancha, 1998.

Municipality (Province)	Collective hunting fee[1]	Private hunting fee[1]	Support to afforestation by the EU[2]	Grazing fee in *polígonos parcelarios*
	pts ha^{-1} yr^{-1}			
Corral de Calatrava (Ciudad Real)	400	2500	20,000	900
Monteagudo de las Salinas[3] (Cuenca)	600	600	20,000	100
Huerta de Valdecarábanos (Toledo)	1333	1333	20,000	500
Torrenueva (Ciudad Real)	1625	2500	20,000	538
Villahermosa[4] (Ciudad Real)	3150	2500	20,000	648
El Ballestero (Albacete)	1700	1700	20,000	650
Motilla del Palancar (Cuenca)	-	1400	20,000	120
Ajofrín (Toledo)	1450	1450	20,000	550
Mean ± SD	1465 ± 896	1748 ± 697	20,000	501 ± 271

[1] Small game [red partridge (*Alectoris rufa*); hare (*Lupus capensis*)]. 1 euro = 166.326 pts.
[2] Maintenance of new plantations (mainly pines) during the first 10 years.
[3] Mainly wild boar (*Sus scofra*).
[4] Lower price in private property because of shrub-dominated land of lower habitat quality for small game.

distribution of the regional flock across available grazing land. The proposal addressing the situation (A_4) reached a very high level of consensus (79%), as both cultivators and pastoralists have common interests on this issue. Large landowners would surely resist a change to the present legal status, but they represent a minority, both in the population of farmers and in the sample. The large group of small owners may see this proposal as a way to eliminate a traditional discrimination on grazing rights transfer between small and large owners. The pastoralists may regard the proposal as a way of increasing available grazing land. However, the new legal framework, recently approved by the regional government (JCCM, 2000) does not change substantially on this issue and thus, in the foreseeable future, the unbalanced stocking between rented and non-rented grazing land is expected to be maintained.

It is clear that large landowners may have freedom to capitalize the land attributes of their properties as driven by economic incentives. We have tried to shed some light on reasons why large landowners lack interest in ownership of a sheep operation. When three alternative attributes (sheep operation, afforestation and renting small-game hunting rights) were compared, it was clear that different economic incentives and social reasons for each alternative are operating. The two first operations are subsidized and are of low social demand, but the hunting operation is market-free and of higher social demand. Landless pastoralists do not press for access to large landowners' grazing land as long as they have access to rented land at fixed and out-of-market grazing fees. Mean grazing fees are some three times lower than hunting fees and a staggering 40 times lower than subsidies awarded to afforestation (Table 4). Large landowners may be lured by subsidies awarded to the sheep operation. Under the general scheme of EU direct payments, a per-head (headage payment) subsidy represents some three times the mean grazing fee at the current stocking rate. However, most large landowners would need to hire a shepherd and this would be the primary operating cost. Most comments by local staff on this issue suggest that larg landowners are favored by per-hectare EU subsidies awarde to cereal cultivation, perhaps supplemented with hunting fee They perceive the sheep operation as a disturbance of their ow cultivation practices and one plagued with scarcity of profes sional shepherds. These observations may suggest that the whol sheep operation should be open to the bargaining of grazing fee between cultivators and pastoralists, and that the EU subsidie awarded to the different attributes of land utilization should b more equitable, taking into account the effects of the distributio of support between sectors and farmers (Caballero, 200 OECD, 2000).

The strategy of promoting the hectarage of forage legumes a a complementary forage and regulator of seasonal availability c feed resources (proposal A_5) reached a consensus of over 80 without any major disagreement between cultivators an pastoralists. For cultivators, this strategy represents a chang from the dominant cereal–fallow rotation to a cereal–legum rotation. Most cultivators are aware of the economic an environmental benefits of rotating cereal and legumes becaus this practice was well established in the farming system whe the mixed cereal and sheep operation was more prevalen Ironically, when farmers were consulted in 1998, the EU suppo schemes promoted idle land (fallow) but not forage legum production. Currently, cultivators might be more supportive a under a new regulation, 1257/1999, annual forage legumes a eligible for subsidy. Pastoralists may regard the strategy as a wa of increasing the supply of good-quality forage, also at low prices.

Cultivators and pastoralists shared a view on the enviro mental benefits of mixed-farming systems (87% either agreed strongly agreed with proposal B_1). A minority of farmers (42% agreed or strongly agreed with the environmental hazards proposal B_2 (disturbance of cultivation practices and so damage). However, when the mean farmers' response in suppo of proposal B_2 was divided by groups, that of the cultivato

(63%) differed ($P<0.001$) from that of the cultivator–pastoralists (30%) and landless pastoralists (24%). The reaction of farmers should be considered to be more of a perceived view of the traditional grazing system than an appraisal of an improved system that has been proposed but not implemented. The very high rate of consensus on the potential environmental benefits of mixing cereal and sheep production is probably more illustrating than the divergent views on potential hazards. The consensus reflects the entrenched potential of a strategy of agricultural development. The divergent view of a majority of cultivators reflects the very low stake of this group in the management of the grazing system. Comments on this issue received from the local staff suggest that in the day-to-day business operation some occasional disturbance of cultivation practices by the sheep operation may occur, but the farmers were more concerned with economic decay derived from unrestructured systems than with occasional damage caused by the sheep operation.

A new legal and institutional framework

The divergent views between the two social groups were again revealed when the question was posed of whether grazing resources should be considered in the light of private or public good (C_1). The first alternative would imply that access to grazing resources should be linked to land property while the second would consider grazing resources within the public domain. The general mean of our sample (53%) indicated that a low majority of farmers favored the proposal of linking grazing rights to land property, but when the response was divided by group, there was a significant ($P<0.001$) difference between groups. A majority of cultivators (76%), either agreed or strongly agreed, against a clear minority of cultivators–pastoralists (35%) or landless pastoralists (38%).

The legal basis of the cereal–sheep grazing system has been questioned under the assumption of interference with property rights (De la Cuesta, 1991; Nieto, 1959), but the consensus agreement has been operative for centuries (Ruiz and García, 1998). Most cultivators abide by the law under a sense of social responsibility, but their responses suggest they neither see themselves as real stakeholders in the management of the system nor as receivers of comparative benefits. Comments by the local staff on this issue indicated that most cultivators do not restrain the access of flocks to their grazing land, but they do not expect cooperative behavior for sensible use of the grazing resources.

A revamping of the system based on the majority principle would be difficult to apply in the bargaining of grazing rights, because of the unbalanced number of the two groups (a mean of 80 cultivators per *polígono* to one landless pastoralist). As the cost of self-exclusion under current grazing fees would be very low (Olson, 1971), even a minority of self-excluded cultivators would hinder the utilization of the *polígonos*. In our view, grazing rights should be kept within the public domain, but the stake of cultivators and pastoralists should be balanced, especially on the bargaining of grazing fees.

When farmers were surveyed in 1998, a legal and institutional void was apparent. The last institution in charge (Cámaras Agrarias) was abolished in 1996. Thus it was hardly surprising that the proposal to fill the void (C_2) reached the highest level of consensus (90%) within farmers of the two social groups (Table 3). It is unknown whether the new legal framework (JCCM, 2000) will accomplish the expectations of the stakeholders and the general welfare of the society as a whole.

Regarding the subject of this research, the new legal framework may fall short of expectations on seven major issues:

1. Grazing rights remain under the public domain, but the stake of cultivators and pastoralists remains unbalanced.
2. The question of the segregation of grazing rights awarded to large landowners is inadequately addressed as to implications on the spatial distribution of stocking across available grazing resources.
3. The new law transferred responsibility for grazing management from the agriculture staff to the local administration (town and village councils) without foreseeing the need for managerial and technical support to these local institutions. Ironically, adaptation and implementation of EU policy support directives on extensive grazing systems (i.e., Regulations 1257/1999, 1750/1999 and 2603/1999) remain under the responsibility of national and regional agriculture staff.
4. Grazing fees at local levels are fixed within a limited range, as in the old regulations, by the Provincial Grazing Commissions (Comisiones Provinciales de Pastos). Under the new legal framework, competition for access to grazing resources and bargaining of grazing fees will be limited. Fixed grazing fees, larger flocks, scarcity of labor and harsh working conditions in flock management tend to promote poor allocation and use of grazing resources. Shepherds paying a low and out-of-market grazing fee are motivated to take leased land but not to increase grazing-days. The new law does not tie leasing to a minimum use of grazing resources nor differentiate between indoor-dominant feeding and resource-linked operations. This point is essential for the maintenance of the extensive sheep operation and corresponding identity of regional products (dairy cheese and meat).
5. The Local Grazing Commissions (Comisiones Locales de Pastos) will be composed of three cultivators, three shepherds and one representative of the local council. They will be in charge of developing the local grazing management plan (Ordenanzas Locales de Pastos). However, development of practical management plans will require reshaping the grazing resources and grazing infrastructures within the *polígonos*, allowing landless pastoralists to own small plots, assembling tiny plots into more efficient structures, controlling mobility of grazing rights among pastoralists, and controlling compliance with EU regulations and distributions of subsidies. The Local Grazing Commissions will need technical tools and managerial support to plan and implement this daunting task.
6. Grazing developments will require access to technical expertise and long-term capital. Landless pastoralists have little of either, and the new grazing law will make it more difficult for them to obtain capital if they do not have access to property and security of tenure. Investors need to be sure that the law will not work against them in the future.

7. The new law is more of an adaptation to political freedom in Spain than to new social and economic realities. The transfer of grazing rights should be open to competition. The openness that a publicly accessible land (*polígonos*) register would bring would probably be unacceptable to most present users, but would be in the general interest of the public.

We cannot anticipate in advance the degree of implementation and long-term consequences on grazing management of the new legal and institutional framework. Legal and institutional adjustments all require a previous comparative estimate of benefits (and costs) between traditional and improved systems. We have attempted to undertake such a task within constraints of available data in the cereal–sheep system of Castile–La Mancha. Policy reforms are required to achieve economic and environmental benefits, but there is a danger of moving ahead with a policy that is ill-designed and does not take into account the long-term benefits of improved grazing systems.

Conclusions

This work showed that traditional grazing systems are not always associated with practical use of resources and absence of environmental concerns. A revamping of traditional grazing systems should develop technical strategies that provide economic and environmental benefits and take into account the social and structural fabric where they are to be implemented.

The traditional cereal–sheep farming system of the Castilian Plain needs to clarify its image as a sound ecological operation that can adapt to new social and economic realities. The current trend is toward a more intensive system, with feeding practices progressively unrelated to grazing resources and use of more foreign sheep breeds. Under this circumstance underuse of resources is of greater concern than overgrazing, and the identity of regional animal products is at risk. This work showed evidence of a poor spatio-temporal distribution of stocking levels across the available grazing resources, and concern about manure management.

The prescriptive phase of our typology analysis showed that the two main stakeholders of the grazing system (small owner-cultivators and landless pastoralists) were in agreement with the proposals for reform. They agreed on requirements for revamping the grazing infrastructure of the grazing allotments (*polígonos de pastos*), plans to allow landless shepherds to own small plots, options for regulating segregation of grazing rights transfer, opinions on environmental benefits of mixed-farming systems, and reform issues of the legal and institutional framework. However, they diverged on their opinions of potential environmental hazards, and legal status of grazing rights.

The environmental outcome of improved grazing systems cannot be fully assessed until these are implemented. What this normative research has shown is that cultivators and pastoralists share consensus on provisions required to reform the grazing system. This point may imply that the main objective of a CAP reform should be to strengthen the social cohesion (community-based subsidies) within the grazing system.

After empirical evidence was collected and farmers we questioned, the regional government promoted and approved new regulation. The new provisions do not appear to address th main concerns, although proper accountability of the new syste cannot be assessed until implementation. The new regulation however, hardly reflect the main findings of this research.

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Assessing students' preparedness towards sustainability in US and European undergraduate agricultural curricula

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Abstract. *This work focused on the evaluation of undergraduate curricula in agriculture for a selected group of institutions fro Louisiana and Texas in the US, and France and Italy. The primary research objective was pursued through the measurement knowledge acquisition in sustainable agriculture principles of undergraduate students as they were approaching the completion their curriculum. Quantitative data were collected through the administration of a test to eight samples (n = 20) of senior studen from each university participating in the study. An analysis of frequencies for every test question indicated the strengths but also th weaknesses that still exist in the agricultural curricula when students' academic achievement was measured. Every institutio acknowledged the emerging sustainable agriculture paradigm in brochures, catalogs and web sites. There is a need for amelioratin agricultural curricula as the long-term productivity of farms is threatened by market policies uncontrollable by single produce and by the manipulation of resources that frequently accelerate environmental degradation. Therefore, we show opportunities fo the strengthening of study programs to incorporate sustainable agriculture principles in undergraduate curricula.*

Key words: assessment, curriculum, evaluation instrument, sustainable agriculture

Introduction

Although curricula in agricultural universities rest upon similar foundations, a variety of subtle differences may occur when study programs are compared among various institutions around the world. The vocation of a certain geographic area to typical crops, or a well-established market niche for particular commodities, may be considered as some of the reasons for the diversity among curricula in agriculture. Colleges and universities have always offered a wide array of academic majors to lead students toward a field of specialization in addition to the mandatory core of courses in the biological and physical sciences that are prerequisites for junior- and senior-level courses. Emphasis on specialty fields has been criticized by an increasing number of agriculturists and other concerned scholars as a reductionist approach of imparting knowledge in the agricultural sciences (Berry, 1996; Borsari, 1998; Jackson, 1985). This faction also has become critical of farming practices that are predicated on a linear mode of teaching agriculture. Concerns focus on threats to the viability of farming systems that must remain productive in the long term (Gliessman, 1998; Orr, 1992; Rodale, 1972; Soule and Piper, 1992), and on alternatives that are more ecologically sound and socially just. The chronic malaise affecting modern agriculture is a symptom of crises affecting field operators over the past five decades. This is n evident, however, because within the last half of the 20th centu modern agriculture has been capable of achieving goals th could have not been conceived even by the most illuminate minds less than a generation ago. Therefore, under the impet of a rapidly changing agriculture, curricula have been designe to fulfill the immediate needs of modern farming systems and t prepare specialists, who are ready to enter the labor work forc in a very dynamic agricultural industry.

Bezdicek and DePhelps (1994) criticized conventiona agricultural education because of its constraints in linea thinking and decision making. Their approach to educatio rather entailed the study of integrated systems of crops, livestoc and management practices. Land-grant universities experienc major difficulties in operating the transition to a sustainab agriculture approach, in part because of well-establishe associations with agrochemical companies and food corporatio that predominantly fund their research and academic progra (Berry, 1996; Orr, 1992; Rodale, 1972; Stauber, 1994). As th acquisition of new knowledge from field experiments demo strates connections among agricultural crops and ecosystems (Titi and Landes, 1990; Gliessman, 1998; Jackson, 1985; Sou and Piper, 1992), sustainable agriculture principles superce conventional agricultural models. Despite new findings and renewed dialogue, modern agriculture remains in a profou socio-economic and environmental crisis. Colleges of agricu ture are not immune to this malady in that it impacts student recruitment and retention (Russel, 1993).

Various studies (Fairnie et al., 1989; Litzenberg a Schneider, 1987) indicate that despite specialist trainin

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traditional approaches in agricultural education have not satisfactorily prepared graduates for managerial roles in a commercial environment. Major weaknesses in course content include a lack of emphasis on the agrifood sector's world role, inadequate business management training (even for agribusiness majors), and an inability to effectively communicate verbally or in writing (Collins and Dunne, 1996). Many views still exist regarding the nature of a sustainable agriculture, as well as how it can be achieved through a renovated educational effort (Altieri and Francis, 1992; Altieri and Rosset, 1996; Gliessman, 1998; Keeney, 1989; Kirchmann and Thorvaldsson, 2000). The need to facilitate changes in agricultural education is becoming widely recognized (Faustman et al., 1996; Townsend and Kunkel, 1996). Despite the strong emphasis on student specialization and the lucrative aspects of farming in conventional agriculture curricula, employers realistically conclude that even the best-prepared graduates will need some form of training as soon as they enter the workforce.

In order to counteract the fallacies of present curricula and to satisfy an increased public awareness concerning the environmental impact of modern farming, some colleges of agriculture have become receptive to sustainable agriculture issues and to a philosophy of sustainability. Some institutions are redesigning their curricula to be more compatible with social change and with a global agricultural context (Silletto et al., 1993). However, it is not yet determined whether these institutional changes include an emerging sustainability philosophy that educates students to manage natural resources more responsibly for the long-term prosperity of farms and their neighboring human communities.

Plausible Causes of the Modern Agricultural Crisis

Modern agriculture has a rich and productive history, especially regarding farm output and worldwide trade of agricultural commodities. However, the vulnerability of conventional farming systems to a global economy alarms today's scientists and concerned citizens, who realize that changes must occur if the long-term prosperity of modern farms is to be maintained. Many producers go out of business every year despite the availability of high technology and various other resources provided by universities and industry (Callicot, 1990; Rodale, 1972). The environmental crisis that is affecting agriculture is leading more and more toward a path spiraling out of control (Carson, 1962; Leopold, 1999). During the past 50 years, agriculture has been transformed into an industrial activity in Western countries. This model has quickly become dominant and its hegemonic power has often contributed to a demise of millenarian agropastoral cultures. Where these ancient systems have been able to withstand the impact of the 'green revolution', agriculture remains a primary human activity at the level of subsistence. This enormous diversity among farming systems requires operators with appropriate skills suited to particular rural environments. However, with an increasing demand for food and fiber to satisfy the needs of a growing human population, scientists have been witnessing the detrimental impact of modern agriculture on both natural and human settled habitats. Environmental costs of cultivated crops remain enormous (Rodale, 1976; Jackson, 1985; Ablemann, 1993). In less than a generation we have passively observed and, in many cases, encouraged the disappearance of rural communities and the rise, on a global scale, of massive urbanization. Land-grant universities have reacted to this complex situation by 'blindly believing' that increasing production efficiency would help to heal the agricultural crisis. Unfortunately, this reductionist *modus operandi,* embraced by a majority of educational institutions, has been 'helping' to ensure the economic collapse of small family farms, and this loss of farmers consequently has reduced their political influence (Beus and Dunlap, 1990). Only 35 years ago, 18% of Americans participated directly in farm production whereas in the 1980s, only 2% of the population produced our food (Schumann, 1987), and at present we are probably below that percentage. However, concerns are limited because a primary objective is the short-term profitability of modern farming systems. With this logic in mind, professionals working in the field usually make decisions driven by markets, while detrimental consequences to agroecosystems are inimical to the environment and compromise sustainability.

Students' Achievement as an Indicator of Sustainability in the Agricultural Curriculum

Enhancing the professional capabilities of all the operators working in the field has become a tangible necessity (Kunkel et al., 1996; Lockeretz, 1997). The fulfillment of this educational objective may be pursued through an assessment of knowledge of sustainable agriculture concepts and issues among undergraduate students who are approaching completion of their study program. This effort will have direct repercussions for the betterment of human communities and their environment, and it will contribute to more holistic inquiries when students challenge the study of agroecosystems.

The use of the multiple-choice test proposed in this study may further promote discussion among agricultural educators regarding sustainability and shake the conventional certainties of an obsolete knowledge for the improvement of curricula in agriculture. The pursuit of this goal will make the effort of conducting this preliminary investigation at the international level a tangible contribution to agricultural education reform. The purpose of this investigation is to evaluate the level of academic achievement in sustainable agriculture among selected samples of undergraduate students. This research may provide recommendations to agricultural educators on how to improve the quality of undergraduate curricula in agriculture and to make them more suitable to the challenges of the 21st century.

It must be clarified, however, that the purpose of developing a measuring tool to evaluate curricula in agriculture is not to trigger competition among institutions but rather to provide valuable recommendations for the improvement of curricula (Ernst, 1989). The goal is to ameliorate the undergraduate agricultural curriculum and to provide students with an opportunity to learn about the functioning of integrated farming systems, while fostering their interests towards holistic manage-

ment (Pilione, 1998). The data generated by this instrument may stimulate the community of agricultural educators and agriculturists by challenging their efforts and thoughts regarding the sustainable philosophy. As a result of changes in the curricula, a new generation of agriculturists should become better educated to meet the challenges of agriculture in the next millennium.

Methods

Senior students of either sex majoring in agriculture were the subjects in this study and they voluntarily agreed to participate. A convenient sample considered 20 students each ($n = 20$) for every university involved. The protection of human subjects was a priority requirement. The selection of a limited number of institutions to be included in this evaluation was a recognized constraint. Even within the US, such a limitation would have been inevitable because of the enormous number of colleges and programs in agriculture. The involvement of institutions was based upon their willingness and interest in participating in the study. The decision to include foreign institutions offered an international perspective. Initially, the establishment of contacts with some faculty members and administrators of the universities was a vital preliminary step to verify their desire and interest in participating. Italy was selected because the principal investigator is a native of that country and familiar with its educational system. France was selected because of the investigators' fluency in the language.

The instrument consisted of a 25 multiple-choice question test that was validated through a jury panel system, employing seven experts in sustainable agriculture, who were asked to review an initial list of 50 words. They had to select 25 terms that they thought most appropriate to evaluate students' preparedness, or propose their own terms to the list. These concepts were classified in three different groups (very important, if chosen by a minimum of six panelists; important, if chosen by a minimum of five panelists; new key concepts, terms that were not included in the initial list of terms). Frequent communications occurred among the authors and the panelists until a consensus was achieved to utilize appropriate concepts that were used to formulate the 25 questions (Table 1).

Borsari and Vidrine (2000) contend that this test format was the most flexible for use by US and foreign universities to collect promptly the necessary data needed to quantify students' comprehension of sustainable agriculture principles and issues, as presented by the evaluation instrument. Despite the equivalence of essay responses and multiple-choice questions in producing valid data (Bennet et al., 1991), the authors opted for a multiple-choice format in order to administer the test consistently, also across the borders of foreign countries. For every question there were four possible answers, but students were asked to select only one (Table 2). The test was translated into Italian and French. The subjects were tested in April 2000 with the assistance of a cooperative faculty member at every institution that participated in the study.

Test Results

The student tests were returned to the authors via mail a were scored during the summer term of 2000. A summary tab reported the frequency of correct answers for each institution f each of the 25 concepts under investigation.

The mean ($M = 0.5152$), the standard deviation (SD = 0.216 and the frequency range (range = 0.00–0.80) represent t descriptive statistics that were calculated from the percenta of correct responses for each question. The identification of the variances from the mean is used to indicate students' academ strengths and weaknesses in varied areas of sustainab agriculture. Blank responses were considered as an indicati of lack of knowledge and were counted as errors (Tables and 4).

For purposes of this initial discussion, each institutio represents a unit for analysis. It appears that certain concep such as 'humus', 'biomass', 'biodiversity', 'ecology', 'mon culture', 'polyculture' and 'carbon/nitrogen ratio', seem to clearly comprehended by the students in that every frequency above the mean. In particular, the term 'polyculture' shows th 62.5% of the frequencies are above the mean by one standa deviation, and for concepts such as 'humus' and 'monoculture half of the frequencies are also above the mean by one standa deviation. For the concepts 'ecology' and 'carbon/nitrog ratio', 25% of the frequencies are above the mean by o standard deviation, whereas, for 'biomass' and 'biodiversity 12.5% of the frequencies were one standard deviation above t mean. Responses for the term 'sustainable agriculture' indica students' knowledge of the topic, except for the sample of one the two Italian universities, which scored a frequency of 0.40. similar condition was detected for the concepts 'rotation grazing' and 'rhizosphere', where the student sample from o of the two universities from Louisiana scored the lowe frequencies of 0.24 and 0.44, respectively.

The concept 'agroecosystem' was scored the highest amo all the institutions except for one of the two student sampl

Table 1. List of key concepts adopted for the construction of t student preparedness test (modified after Borsari and Vidri 2000).

Very important	Important	New key concep
Agroecosystem	Biomass	Local food syste
Biodiversity	Alternative agriculture	
Biological control	Green manure	
Compost	Holistic management	
Ecology	Humus	
Integrated pest management	Integrated farming system	
	Rotational grazing	
Monoculture	Succession	
Ecological niche	Synergism	
Polyculture	Systemism/holism	
Reductionism	Carbon/nitrogen ratio	
Sustainable agriculture	Eutrophication	
	Rhizosphere	

Table 2. Sample questions of the evaluation instrument (test) purposefully designed to measure students preparedness in sustainable agriculture (from Borsari and Vidrine, 2000).

1. The term 'sustainable agriculture' has been used for a couple of decades in order to convey the innovative idea of agricultural systems that are:
   (a) ecologically sound
   (b) economically and socially viable
   (c) integrating various crops, livestock species and management practices
   (d) all of the above
6. An agricultural system conceived as a complex system of complementary relationships between living organisms and their environment within a certain physical area is called:
   (a) functional system
   (b) agroecosystem
   (c) farm
   (d) cultivated field
9. Which of these phrases is likely to provide us with the most valid and direct evidence of an integrated farming system?
   (a) a system in which IPM is commonly practiced
   (b) a system highly specialized in maximizing yields and profits from a major crop
   (c) a system that is diversified in terms of crops, livestock and activities
   (d) none of the statements above is correct
16. A farming system that includes the simultaneous growing of several, different species is known as:
   (a) polyculture
   (b) primitive agriculture
   (c) subsistence farming
   (d) monoculture
25. Disregarding the various technical practices within a sustainable agriculture system, which of these economic strategies do you see as the most valid in support of the sustainable agriculture philosophy?
   (a) food scale economy
   (b) local food system, such as a community-supported agriculture
   (c) monopoly by few food corporations
   (d) subsistence food economy

from Texas (two standard deviations below the mean). On the other hand, the test results show frequencies below the mean for all the institutions, when students were asked questions about 'eutrophication'. For this key concept, 25% of the frequency scores were two standard deviations below the mean, and half were one standard deviation below the mean. For the term 'reductionism' 25% of the frequency scores were also two standard deviations below the mean and another 62.5% were one standard deviation below the mean. For the concept 'holism', 62.5% of the frequency scores were one standard deviation below the mean. The frequencies of correct answers were also below the mean, by one or two standard deviations, for the following concepts:

- Holistic management (with minimum frequency score by one of the Texas samples that was more than two standard deviations below the mean).
- Succession (with the exception of a Texas institution whose score was slightly above the mean).
- Alternative agriculture (with the exception of a Texas institution whose score was slightly above the mean). For this concept, all of the European universities were one or more standard deviations below the mean.
- Compost (with the exception of the samples from a school from Louisiana, and a French school that scored slightly above the mean).
- Green manure (with the exception of one of the two French universities that scored slightly above the mean). For this concept three out of four of the US universities scored frequencies that were one and two standard deviations below the mean.

The remaining key terms of the students' test had a larger variation of correct responses versus wrong responses. The concept 'biological control', for example, revealed frequency scores below the mean for more than one standard deviation for one of the universities from Louisiana. One Italian institution obtained the frequency score for this term that was one standard deviation above the mean, whereas the remaining 75% of the frequency scores were clustered around the mean. For the concept 'ecological niche', 75% of the European institutions had frequency scores below the mean of approximately one half of a standard deviation. Similarly, the term 'integrated pest management' had frequency scores clustered around the mean. Only one Italian university had the frequency score one standard deviation above the mean for this concept. The term 'integrated farming system' revealed frequency scores one standard deviation above the mean for 75% of the US institutions and two standard deviations below the mean for half of the European institutions. The results for the term 'local food system' illustrate a different scenario. In this case, the low-frequency scores were obtained by the US student samples (75% of the frequency were one standard deviation below the mean), whereas 75% of the European student samples obtained frequency values above the mean. In order to further secure the validity of the evaluation instrument, a goodness of fit test on the students' test scores was performed.

Table 3. Summary of test results from the European universities. Colored in gray are the frequencies of correct test results or standard deviation below the mean and in bold are the frequencies one standard deviation above the mean value[1].

Key term[2]	France I	France II	Italy I	Italy II	Mea
Sustainable agriculture	0.64	0.52	0.52	0.4	0.52
Biological control	0.6	0.44	0.68	0.72	0.61
Ecological niche	0.6	0.32	0.48	0.36	0.44
Humus	**0.76**	0.8	0.72	0.76	0.76
Biomass	**0.76**	0.64	0.64	0.68	0.68
Agroecosystem	0.72	0.6	**0.76**	**0.8**	0.72
Biodiversity	0.56	**0.76**	0.64	0.68	0.66
Rotational grazing	0.68	0.72	0.6	0.56	0.64
Integrated farming system	0.04	0.08	0.24	0.36	0.18
Ecology	0.68	**0.76**	0.64	0.6	0.67
Eutrophication	0.32	0.44	0.04	0.24	0.26
Integrated pest management	0.68	0.4	0.56	0.72	0.59
Compost	0.68	0.28	0.4	0.2	0.39
Monoculture	**0.76**	**0.8**	0.64	0.72	0.73
Reductionism	0.24	0.28	0.12	0.36	0.25
Polyculture	**0.8**	**0.8**	**0.76**	**0.76**	0.78
Alternative agriculture	0.28	0.24	0.2	0	0.18
Carbon/nitrogen	**0.76**	0.68	0.68	**0.8**	0.73
Holistic management	0.32	0.64	0.32	0.56	0.46
Synergism	0.72	**0.76**	0.64	**0.8**	0.73
Holism	0.28	0.44	0.16	0.28	0.29
Rhizosphere	**0.8**	0.72	**0.76**	0.8	0.77
Green manure	0.4	0.64	0.32	0.4	0.44
Succession	0.32	0.08	0.28	0.16	0.21
Local food system	0.48	0.68	0.56	0.56	0.57

[1] I and II indicate the institutions for each state/country participating in the study.
[2] The first column reports the key terms used for the construction of the students' test.

From this statistical analysis, it could be concluded that the distribution of the test scores was normal, χ^2 (5, $n = 160$) = 2.025, $P > 0.05$.

Discussion and Recommendations for Further Research

The data provided information allowing conclusions to be drawn about the strengths and weaknesses of the knowledge of sustainable agriculture acquired by senior students. Non land-grant institutions and newly established agricultural schools appear to be highly responsive to the need of steering curricula toward sustainability (Townsend and Kunkel, 1996). The interpretation of this trend seems to be attributable to the need of these institutions to develop an alternative image of their college of agriculture that may attract students to enroll in their programs and to remain in them until completion of their studies. Finally, smaller universities may not compete for funding with the land-grant colleges and, therefore, their higher level of independence from the agrochemical companies seems to allow them to be more flexible and receptive to change (Nelson, 1996). Land-grant colleges are attentive to the issue, although they may experience greater difficulties with promoting change in their curricula due to the fragmentation of the college of agriculture in several highly specialized departments. Some changes are taking place, although they are primarily the outcome of individual d departmental sensibility to more sustainable farming practice For example, the Department of Horticulture of one of the U schools has developed a course in organic vegetable productio (P. Hegwood, Louisiana State University, Baton Rouge, LA personal communication, August 4, 1999). Integrated pe management courses are already established in some U universities to broaden students' perspectives in farmin practices and technologies that are more environmentall concerned.

The data generated from this investigation provide only partial answer to the challenges of incorporating principles sustainability into curricula in agriculture, due to the limite number of universities and lack of generalizability. Howeve additional implications for further research have emerged. Fro this consideration therefore, the following recommendations ca be proposed in order to stimulate educators to conduct mo research:

- The incorporation of more institutions in future studies this kind will contribute to a better understanding of th knowledge base in the foundations of agricultural teachin and philosophies.
- Comparative investigations of sustainable agriculture st dents versus their counterparts with regards to continuin

Table 4. Summary of test results from the universities in the US. Colored in gray are the frequencies of correct test results one standard deviation below the mean and in bold are the frequencies one standard deviation above the mean value[1].

Key term[2]	Louisiana I	Louisiana II	Texas I	Texas II	Mean
Sustainable agriculture	0.68	0.68	0.68	0.64	0.67
Biological control	0.52	0.16	0.48	0.52	0.42
Ecological niche	0.44	0.64	0.68	0.64	0.6
Humus	0.64	0.72	**0.76**	0.6	0.68
Biomass	0.68	0.68	0.68	0.64	0.67
Agroecosystem	0.64	0.56	0.08	0.72	0.5
Biodiversity	0.72	0.68	0.6	0.64	0.66
Rotational grazing	0.56	0.24	**0.8**	0.72	0.58
Integrated farming system	0.64	0.72	**0.76**	0.72	0.71
Ecology	0.6	0.72	**0.76**	0.6	0.67
Eutrophication	0.12	0.2	0.08	0.24	0.16
Integrated pest management	0.32	0.56	0.56	0.44	0.47
Compost	0.36	0.56	0.48	0.4	0.45
Monoculture	**0.76**	**0.76**	0.72	0.72	0.74
Reductionism	0.08	0.16	0.08	0.28	0.15
Polyculture	0.6	0.68	**0.76**	0.64	0.67
Alternative agriculture	0.32	0.4	0.52	0.44	0.42
Carbon/nitrogen	0.6	0.72	0.68	0.48	0.62
Holistic management	0.44	0.4	0.04	0.64	0.38
Synergism	0.44	0.36	0.52	0.52	0.46
Holism	0.24	0.36	0.2	0.4	0.3
Rhizosphere	0.68	0.44	0.68	0.68	0.62
Green manure	0.08	0.2	0.4	0.2	0.22
Succession	0.48	0.36	0.16	0.52	0.38
Local food system	0.24	0.48	0.2	0.28	0.3

[1] I and II indicate the institutions for each state/country participating in the study.
[2] The first column reports the key terms used for the construction of the students' test.

education and participation in research will verify the professional preparation of the new generation of agriculturists to respond to environmental challenges.

- The study of the affiliations of the college of agriculture with corporations and agencies will tune philosophies and approaches to the challenges of future food production activities toward a unified theory for sustainable agriculture.

Incorporation of the principles of sustainable agriculture in the curriculum of the new millennium is a real necessity, although not an easy task. This multifaceted challenge remains an inevitable mandate that every college of agriculture will need to address in the near future. Proposing feasible curriculum changes is a matter of universal concern in order to avoid the demise of the colleges of agriculture from the main university and resulting drastic, negative consequences in the management of farming systems. Newsome (1991) illustrates this condition by explaining the interest that has driven fervent discussions in academia in order to ameliorate the crisis into which agricultural institutions have plunged since the agricultural crisis of the early 1980s. In her opinion, a renewed knowledge base for the agricultural sciences will redefine the intellectual purposes of the college of agriculture. It is not the need to regain the traditional status of the land-grant institutions, but rather to achieve excellence in agriculture at every level. This major objective is to be pursued through the capability of the college of agriculture to continue to provide outstanding quality of instruction with limited resources.

Traditional agricultural education has either focused excessively on the science and technology of production or, through the discipline of agricultural economics, on efficiencies of resource use and income distribution in the farm sector (Collins and Dunne, 1996). Curriculum development may begin either with a general assessment of needs, or with a specific problem the curriculum designer attempts to resolve (Pratt, 1980). A curriculum in sustainable agriculture must reiterate the efficacy of the learning process in a synergistic effort in which all the figures involved in agriculture (farmers, extensionists, researchers, students) are contributing effectively to the acquisition of new knowledge built on the initial experiences of our farming ancestors. These are the auspicious philosophical approaches for beneficial and systemic change in modern agricultural education.

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Dry matter and fiber yields, and the fiber characteristics of five nettle clones (Urtica dioica *L.*) organically grown in Austria for potential textile use

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Abstract. *Fiber nettle* (Urtica dioica *L.*) *has potential as a fiber crop in the natural textiles industry, an industry requiring production by organic methods. No recent data on yield potentials and quality of this crop using these methods are available to farmers. Five fiber nettle clones were cultivated between 1997 and 1999 in a randomized block design with four replications per clone on an organic farm in Lower Austria. The harvests from the second and third cultivation year were used for further analysis. The dry matter yield (stalks) of the five nettle clones in the second cultivation year (1998) ranged from 2.3 to 4.7 Mg ha $^{-1}$. The dry matter yield of the third cultivation year (5.6 to 9.7 Mg ha^{-1}) was more than double that of the second year. The large increase in the yield of the third year was a result of an increase in the height (20 to 40 cm higher) and a doubling of the number of stalks per plot compared with those from the second cultivation year. Undersowing with clover had a positive effect on fiber nettle growth. The fiber content after chemical processing ranged between 8 and 16% of the dry matter in both the second and third cultivation years. The fiber yields ranged from 335 to 411 kg ha $^{-1}$ in the second year and from 743 to 1016 kg ha $^{-1}$ in the third year. Clones with a high dry matter yield had a low fiber content and vice versa. There was no significant difference in the fiber quality (fiber strength, elongation, fiber fineness, length of fiber) of the five nettle clones. Due to the different consistency in the upper and lower part of the stalk and to fiber processing methods, the fiber material is generally very heterogeneous. This work shows that the cultivation of fiber nettle by organic methods in Austria is possible and that it produced well in the third year. Organically grown fibers of nettle are suitable for textile use; however, further development of an economic and functional high-yielding method for fiber processing, and efficient marketing are essential for the success of nettle fiber in the textile market.*

Key words: eco-textiles, fiber plants, organic farming, renewable resources

Introduction

Before cotton (*Gossypium* sp.) became the most important fiber material for textiles in Europe, people used fiber plants that grew under domestic climatic conditions. Flax (*Linum usitatissimum* L.) and hemp (*Cannabis sativa* L.) are well known, but the fibers of nettle (*Urtica dioica* L.) were also once used for textile purposes. The use of bast fibers of nettle was first documented in the 12th century (Hegi, 1981), and it is believed that people at that time used wild nettle plants that grew near settlements. Cultivation of nettle started in the 19th century (Bredemann, 1959). During the First and Second World Wars, fiber nettle was promoted as a substitute for cotton (Bredemann, 1959; Grafe, 1928). About 500 ha of fiber nettle was cultivated in Germany and Austria in the 1940s and used for textile production (Bredemann, 1959), after which the crop was no longer produced. Processing facilities for nettles were destroyed during the Second World War and other cheaper fibers were more easily available (Waskow, 1995). Recently, natural fibers produced by organic methods have received interest, and processors and traders of organic textiles have sought to diversify their products by introducing nettle fibers into the organic textile market.

Fiber nettle is a cultivated form of the wild nettle. Fiber content was increased from about 5% in wild nettle plants to up to 17% of stalk dry matter in the cultivated species (Bredemann, 1959). Bredemann used 170 nettle provenances in over 30 years of breeding (1918–1950), from which the most efficient clones were chosen for crossing. His criteria for breeding were: frost-tolerance, good growth (long and not ramified, straight and stable stalks, many leaves and strong tillering) and high fiber content (Bredemann, 1959). Clone varieties dating back to Bredemann are still maintained at research institutions in Germany. However, the fiber content documented in recent experiments by several authors (Table 1) is not as high as that reported by Bredemann (1959).

To provide organic fiber nettle growers and processors with recent local results on response to cultivation, a research project was started. The aim of this research was to quantify the yield,

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Table 1. Fiber content of fiber nettle (literature overview).

Range of fibre content (% of stalk dry matter)	Processing and analyzing methods	Material	Literature cited
1.8–12.7	Chemical extraction with lye, more detailed information in Dreyer et al. (1996)	27 clone varieties developed by Bredemann	Dreyer and Dreyling (199
1.2–12.7	Chemical processing method (adapted method of Bredemann, 1959)	6 clone varieties developed by Bredemann	Dreyer et al. (1996)
5.5–9.0	Chemical process according to Bredemann (1959), gravimetric	1 clone variety developed by Bredemann	Köhler et al. (1999)
7.4–14.5	Chemical process according to Bredemann (1959), gravimetric	3 clone varieties developed by Bredemann	Schmidtke et al. (1998)
12.6–15.4	Adapted method of Heyland et al. (1995)	2 clone varieties 'Dornburg 1' and 'Dornburg 5'	Francken-Welz et al. (199
8.1–16.0	Mechanical processing (decortication, opening) and succeeding chemical processing (alkali boil-off)	5 clone varieties developed by Bredemann	Hartl and Vogl (2000a)

fiber content and fiber quality of five fiber nettle clone varieties for textile use, cultivated according to the standards of organic farming.

Materials and Methods

Five fiber nettle clone varieties (nos. 1, 5, 7, 8 and 9 of the Agency of Agriculture in the province of Thüringen in Germany, Thüringer Landesanstalt für Landwirtschaft in Dornburg) were grown in a randomized block design, with four replications per clone variety, from 1997 to 1999. In this paper, the term 'clone varieties' is used for genetically identical nettle plants obtained by vegetative propagation. Those clones are, however, not officially registered varieties. The field trial was conducted on an organic farm in Neulengbach, Lower Austria. This farm started conversion from conventional methods in 1996. It was managed according to the EU Council Regulation 2092/91, starting from 1996 and has been certified as an organic farm since 1998. As a consequence, synthetic N fertilizers and herbicides, which would have been applied in conventional agriculture, were not used. The crop preceding the field trial was a 1 year crop of lucerne (*Medicago sativa*). The soil of the experimental field is a Calcaric Cambisol from till (sandy loam texture) (BMLF, 1978). Annual mean precipitation is 794 mm (1997, 960 mm; 1998, 751 mm; 1999, 712 mm); about 50% of the annual precipitation occurs between April and August and the annual mean temperature is 8.6°C (ZAMG, 1999).

The top cuttings of five nettle clone varieties were grown organically in a greenhouse for 5 weeks and planted on 30 May 1997 with a distance of 1 m between rows and 60 cm within rows. After having been planted in the field, the young nettle plants were irrigated twice. During the month of June until August of the first cultivation year (1997), the nettle field was harrowed by hand five times. The inter-row space was rotavated and underseeded with clover (*Trifolium repens*) in early August. Due to the weed suppressing effect of clover, no additional weed control was necessary in the first cultivation year. In 1998 and 1999, only limited weed control was necessary to reduce thistles (*Cirsium arvense*) and grasses. In both years the clover

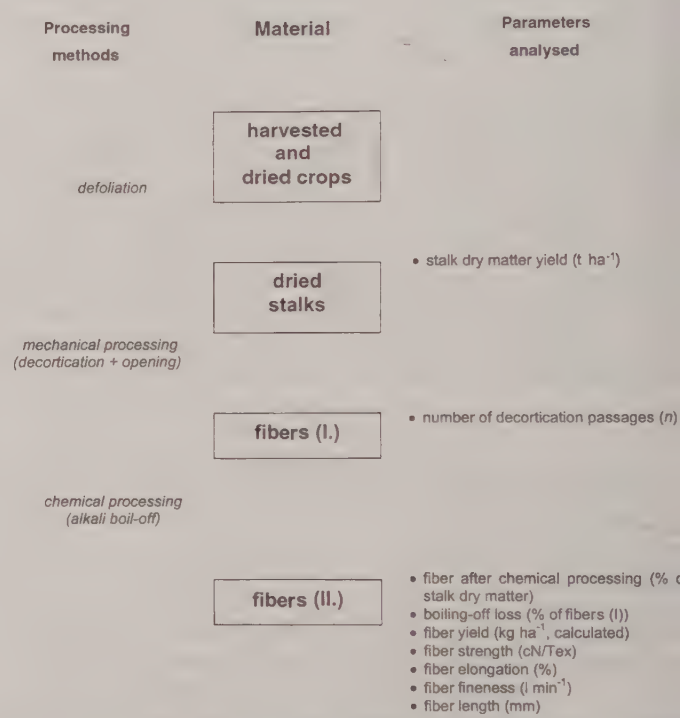
Processing methods
Material
Parameters analysed
harvested and dried crops
defoliation
dried stalks
• stalk dry matter yield (t ha-1)
mechanical processing (decortication + opening)
fibers (I.)
• number of decortication passages (n)
chemical processing (alkali boil-off)
fibers (II.)
• fiber after chemical processing (% o stalk dry matter)
• boiling-off loss (% of fibers (I))
• fiber yield (kg ha-1, calculated)
• fiber strength (cN/Tex)
• fiber elongation (%)
• fiber fineness (l min-1)
• fiber length (mm)

Figure 1. Fiber processing methods used and parameters of fib content and quality analyzed.

established a dense soil cover in spring, later complemented by dense soil cover of nettle. This soil cover of nettle almost kill the clover in summer; however, the clover recovered again spring. Germinating nettle seeds were not observed on the plo To avoid the mixing of different clone varieties caused by runn growth, the rows were separated by inserting plastic strips in the soil.

In 1999, some caterpillars (e.g., *Aglais urticae*) were remov from the nettle plants by hand. Some stalks exhibited a twist growth form, possibly caused by weevil larvae. In 1998, t leaves of clone variety no. 1 showed some minor damage as result of gall mites.

Diluted cattle slurry, available at the farm where the field trial was conducted, was applied to the plots at the following nutrient rates and times: 16 kg N ha^{-1} (26 June 1997); 23 kg N ha^{-1} (23 April 1998), 34 kg N ha^{-1} (19 June 1998), 40 kg N ha^{-1} (27 August 1998, after the cutting); 40 kg N ha^{-1} (4 June 1999).

Since fiber nettle does not provide sufficient yields in the first year of cultivation (Bredemann, 1959), the harvests of the second and third years (1998 and 1999) were used for calculating yield and for analyzing fiber content and quality. All clone varieties were harvested at the same time (14 August 1998 and 25 July 1999), based on the description of maturity by Bredemann (1959). After having been cut in summer, the nettle clones sprouted again and established a dense cover before the stalks died in winter. According to Bredemann (1959), high harvest frequencies could weaken the crop, so these sprouts were not harvested.

At present, a large-scale processing method for fiber nettles does not exist. Because the fibers obtained through the mechanical processing steps are not fine enough for textile use, a standardized chemical processing method (alkali boil-off) was used following the mechanical processing (Fig. 1). The processing and analysis methods have been documented in more detail by Hartl and Vogl (2000b). The fiber yields were calculated from stalk dry matter yield and fiber content following chemical processing.

One-way analysis of variance and the Tukey test were carried out using the program SPSS (version 7.5.2) for Windows (SPSS Inc., 1997). The influence of clone variety was considered significant at $P \leq 0.05$. In the figures shown, mean values with different letters indicate significant differences between these values at $P \leq 0.05$. Means with the same letter are not significantly different.

Results

In 1998, the second cultivation year, the stalk dry matter yield (Fig. 2) of the five nettle clone varieties ranged from 2.3 to 4.7 Mg ha^{-1}. The dry matter yield in the third year ranged from 5.6 to 9.7 Mg ha^{-1}, about double that of 1998. Clone variety had a statistically significant effect on stalk dry matter yield: 1998, the yields of clone no. 1 and clone no. 7 were significantly higher than those of clone no. 8 and clone no. 9. In 1999, the yield of clone no. 1 was significantly higher than that of clone no. 9.

The fiber content after chemical processing ranged from 8 to 16% of stalk dry matter (Fig. 3) in both the second and third cultivation years.

The fiber yields (fiber yield = fiber content × dry matter yield) ranged from 335 to 411 kg ha^{-1} in 1998 and 743 to 1016 kg ha^{-1} in 1999 (Fig. 4). Dry matter yield was inversely related to fiber content in all varieties. The differences between the clone varieties in dry matter yield and fiber content were therefore balanced, resulting in little difference in the fiber yield among the clone varieties.

The fiber quality parameters (average of all five clone varieties) in both 1998 and 1999 differed only to a small extent (without consideration of the variation coefficients). The number of decortication passages differed greatly between the 2 years. The fiber strength lay between 28.2 and 36.8 cN Tex^{-1}. Fiber elongation was between 2.2 and 2.7%. The tested clone varieties reached an average fiber length of 27.5 mm (Table 2, which also explains cN Tex^{-1}).

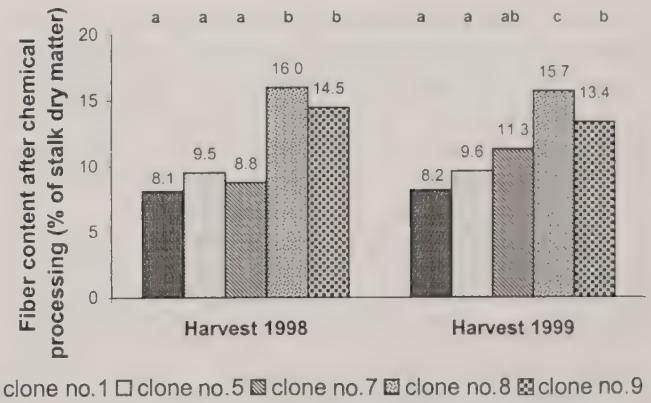

Figure 3. Fiber content of five nettle clone varieties on two harvest dates. Means bars with the same letter are not significantly different ($P \leq 0.05$).

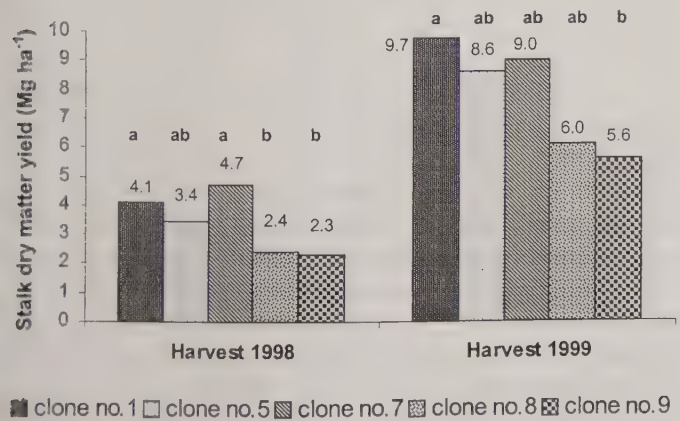

Figure 2. Stalk dry matter yield of five nettle clone varieties on two harvest dates. Means bars with the same letter are not significantly different ($P \leq 0.05$).

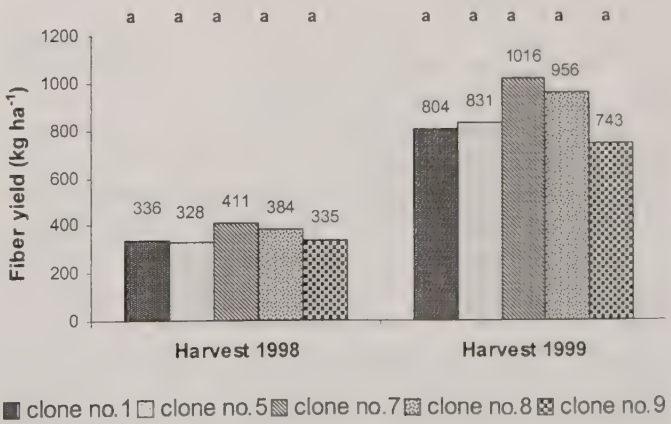

Figure 4. Fiber yield of five nettle clone varieties on two harvest dates. Means bars with the same letter are not significantly different ($P \leq 0.05$).

Table 2. Quality parameters of nettle fibers harvested in 1998 and 1999.

Parameters for fiber quality	1998			1999		
	Mean of 5 clones	Min.[1]	Max.[1]	Mean of 5 clones	Min.[1]	Ma
		Range of CV[2]			Range of CV[2]	
Decortication passages (*n*)	1.8	1.5	2.0	4.7	4.5	5
Fineness (l/min)	17.8	14.8	21.0	14.9	12.2	17
Strength (cN Tex^{-1}) [3]	30.5	28.2	31.6	35.2	31.9	36
CV (%)		*5.9–19.3*			*6.7–23.32*	
Elongation (%)	2.5	2.2	2.7	2.2	2.0	2.
CV (%)		*4.3–16.7*			*3.66–20.94*	
Length (mm)	22.9	20.9	24.3	27.5	26.4	28
CV (%)		*66.5–76.6*			*70.7–89.5*	

[1] Mean values of 4 replications per clone.
[2] Coefficient of variation.
[3] cN Tex^{-1}: Centinewtons per tex (1 tex = 1000 m of thread material weighing 1 g; e.g., 50 tex = 1000 m of thread material weighing 50 g).

Discussion

The stalk dry matter and fiber yields in 1998 correspond to the yields achieved in a cultivation system using no N fertilizer, as reported by Schmidtke et al. (1998), who obtained dry stalk matter yields of 2.19–4.93 Mg ha^{-1} and fiber yields of 300–600 Mg ha^{-1}. The stalk dry matter yield of the second cultivation year (1998) was far below the yield of 4.4–7.3 Mg ha^{-1}, obtained with N-intensive cultivation, as described by Vetter et al. (1996). However, our stalk dry matter yield in 1999 was higher than the yields achieved in this N-intensive cultivation system with 200 kg N ha^{-1} + 100 kg N ha^{-1} after the first cutting (Vetter et al., 1996). In 1999, the fiber yield (743–1016 kg ha^{-1}) was almost double the fiber yield of 300–600 kg ha^{-1} obtained by Schmidtke et al. (1998) in a cultivation system using no N fertilizer.

The large increase in the yield of the third cultivation year was unexpected. In that year diluted cattle slurry was applied only once at 40 kg N ha^{-1}, while in 1998 the slurry was applied three times (23 kg N ha^{-1} + 34 kg N ha^{-1} before cutting and 40 kg N ha^{-1} after cutting). Based on Schmidtke et al. (1998) and Lehne et al. (1998), we expected that fiber nettle would have required more N (i.e., more slurry) and that non-application would have resulted in reduced yields.

The increase in the 1999 yield was due to an increase in plant height (in 1999 the stalks were 20–40 cm longer than in 1998) and to an increase in the number of stalks per plot (the number of stalks per plot more than doubled in 1999 due to more runners). According to Vetter et al. (1996), a high planting density of 50 cm × 50 cm in the first year has a positive influence on the yield in the second year. It has yet to be tested whether a high planting density in combination with low N supply and legume underseed will have a positive effect on the second year yield. Francken-Welz et al. (1999) did not find that planting density had a significant effect on yield.

Obviously, the undersowing of clover appears to have a positive effect on nettle yield. It seems that a balance has been established that satisfies the requirements of both plants. spring, the clover sprouted more quickly than the nettle a established a dense soil cover which reduced weed grow Later, the nettle grew over the clover and by summer the net had established a dense cover that either weakened or partia killed the clover. The following spring, the clover received mo light to regenerate, resulting in its regrowth. Presumably t nettle benefitted later from the N that was released by the clov Legumes can release N for the benefit of non-legume plan even during their growth (N transfer) (Brophy et al., 198 However, the amount of N released in the sowing year is, most cases, low [<30 kg N ha^{-1} with red clover (*Trifoli pratense* L.) Schmidtke, 1997].

In contrast, the positive effect of a legume underseed can be confirmed by the experiments of Köhler et al. (1999). T tested grass–clover mixtures (*Trifolium repens* and *Loli perenne*, as well as 17 species of grasses and herbs, mulch or rotavated) led to a reduction in stalk and fiber yield from t third cultivation year on. The negative influence of competiti caused by the undersown species on the nettle yield w obviously greater than the intended stimulation from the supplied by the legume (Köhler et al., 1999). With continuo low nitrate supply in the soil (less than 20 kg N ha^{-1}), especia in the fourth cultivation year, there was an increase mainly in t monocotyl species of the underseed and weeds. At the sa time, there was an increase in soil organic N. Köhler et al. (19 concluded that for a successful integration of underseed in fi nettle production, the following conditions are essential: wide row spacing of 150 cm between nettle rows; (2) repea inter-row soil cultivation before crop cover is established spring; (3) reduction of underseed growth between the middle August and the end of April; and (4) the use of fast-grow legume species, e.g., common vetch (*Vicia sativa*) and crims clover (*Trifolium incarnatum*). Grass species should be avoi (Köhler et al., 1999).

The good weather conditions of 1999—obviously higher precipitation levels in the main growing period than in the same period of the previous year, as well as in the long-term average—seem to have had an additional positive effect. Sufficient water supply in the main growing period has a positive effect on the growth of fiber nettle (Bredemann, 1959).

This result confirms the maximum fiber content achieved in the recent experiments of Dreyer et al. (1996), Dreyer and Dreyling (1997), Schmidtke et al. (1998), Francken-Welz et al. (1999) and Köhler et al. (1999) (Table 1). However, none of the recent experiments achieves the fiber content of 17% as reported by Bredemann (1959). It is likely that processing and analyzing methods have an influence on measuring fiber content (K. Nebel, IFA Reutlingen, Germany, personal communication, 13 November 1998).

Dreyer and Dreyling (1997) consider a minimum fiber content of over 9% of stalk dry matter as a requirement for an economic fiber nettle cultivation. This limit was fulfilled by three clone varieties in 1998 and by four clone varieties in 1999 (Fig. 4). However, as previously mentioned, differences in fiber content and dry stalk matter of the five nettle clone varieties are balanced by the fiber yield per hectare. Therefore, the limit of the 9% fiber content appears only to be justified in the context of such low fiber contents as documented by Dreyer and Dreyling (1997) and Dreyer et al. (1996). In their experiments, the fiber content ranged from 1.2 to 12.7% of stalk dry matter.

There was no statistically significant difference between the fiber quality (number of decortication passages, fiber strength, elongation, fiber fineness, length of fiber) of the five nettle clone varieties. The high variation coefficients (Table 2) indicate very heterogeneous fiber (i.e., fibers with low and high fiber strength, elongation and length of fiber). The strong variation in boiling-off losses can also be explained by the heterogeneous fiber material. In our analysis, stalks have not been divided and different parts of the stalks have, therefore, not been analyzed separately. However, the fiber heterogeneity could be explained by the different consistency of the upper and the lower parts of the stalk (K. Nebel, IFA Reutlingen, Germany, personal communication, 13 November 1998). This observation has also been documented by Bredemann (1959), who states that the upper part of stalks contains less woody material than the lower part. For practical use, it would be better to cut stalks in two and to use the upper part for textile purposes and the lower part for industrial purposes, such as insulation material. Although this would increase costs, it would also improve quality and thus be profitable (K. Nebel, IFA Reutlingen, Germany, personal communication, 13 November 1998).

The highest strength of the tested nettle fibers lies in the range of the fiber strength of cotton, i.e., 15–50 cN Tex^{-1} (Haudek and Viti, 1980). Fiber elongation shows lower values than cotton (6–10%). Depending on quality, the average fiber length of cotton ranges from 25–40 mm. It should, however, be recognized that the cotton staple is much more homogeneous than is the staple of bast fibers (Bredemann, 1959).

According to the quality parameters tested, organically grown nettle fibers are suitable for textile use. The decisive factor, however, is the technical and economic efficiency of the processing technology and the fiber yield of these methods. In order to use nettle fibers to replace cotton ones, their physical characteristics (e.g., length of fiber, fiber fineness, homogeneity) should be selected to match those of cotton. Problems are still posed by parameters such as fiber flexibility (stiffness, fiber elongation) and fiber homogeneity. The processing technologies for nettle should be optimized according to the application intended (e.g., pure nettle yarn or mixed yarn with cotton) and with the aim of homogenizing the fiber material.

Conclusions

The results show that yields and fiber content of organically produced nettle were higher in the third year of cultivation than those achieved and reported in the research conducted by Bredemann (1959), Dreyer et al. (1996), Vetter et al. (1996), Schmidtke et al. (1998) and Francken-Welz et al. (1999). Thus, the cultivation of fiber nettle under the conditions of organic farming in Austria has potential, provided that the fiber processing equipment and consumer demand for fiber nettle textiles exist. In principle, nettle fibers are suitable for textile use. However, further development of an economic and functional high-yielding method for processing is essential. Fiber processing methods must be optimized, taking into account the application intended for the nettle (e.g., production of a pure yarn or a mixed yarn with cotton). Furthermore, there is a need to conduct research into possibilities of using fibers from different parts of the nettle plant for different purposes (e.g., textile and industrial uses).

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USDA research into organic farming

Michael D. Jawson and Carolee T. Bull

America's appetite for all-natural, organic food has grown at the remarkable rate of over 20% annually for the past 10 years. This makes organic agriculture—farming and processing food without the use of synthetic chemicals, such as synthetic pesticides and many inorganic fertilizers—the fastest growing sector of America's agricultural economy. Contrast that to the scarcity of organic items to be found 20 years ago . . . and those only in specialty shops. Today, organic selections are as easy to find in conventional supermarkets and mainstream stores as in natural food stores.

In fact, mainstream stores altogether account for 49% of organic retail sales, just exceeding the 48% logged by natural food stores. Organic items are flourishing in other direct venues, including farmers' markets, farm stands, roadside stands, farm subscriptions and mail orders. In all, commerce from this array of diverse outlets, large and small, puts America in first place internationally in total organic sales.

The amount of land exclusively dedicated to raising this bounty has also changed. Registered organic land more than doubled in the US during the 1990s, and the transition of conventional fields to strictly organic farmlands continues. In this process, fields are managed organically for 3 years to qualify for certification.

Over the years, organic farmers have closely followed the findings from ARS studies, in particular those on weed management, soil fertility, biological pest control and integrated pest management. Much of ARS' research already aims to increase use of on-farm resources and decrease use of chemicals. For the most part, however, those studies have been done on conventional—not organic—farming systems.

But that's changing. Organic studies—from production to processing—are increasingly a formal part of ARS efforts and can benefit both types of farming systems. In 1998, Congress paved the way for more organic investigations by authorizing an organic farming bill. Some collaborations were already in place between organic farmers and ARS specialists and, in many instances, their university colleagues.

Today, more than 60 ARS scientists are conducting organic farming research. Notably, these studies are on organically certified fields. These experts have consistently made themselves available to local growers for help and advice. For example, ARS researchers in Corvallis, Oregon, are working with organic growers to quell plant diseases. This collaboration is experimenting with compost teas. These teas are made by adding water to organically approved compost and allowing the mix to steep, somewhat like adding water to tea leaves. The mix is then strained, and the resulting tea-colored liquid is sprayed on foliage. The teas may help control botrytis that attacks leaves of blackberries (*Rubus fruticosus* sp. agg.) and ornamentals such as roses (genus *Rosa*) and geraniums (*Pelargonium* × *hortorum*).

Other examples of ARS' organic research include:

- Scientists at Salinas, California, responded to the needs of local organic strawberry (genus *Fragaria*) growers with some first-ever studies. The researchers compared commercially available strawberry varieties grown only on fields managed organically. The work was needed because organic growers cannot use the methyl bromide fumigant, familiar insecticides, and herbicides available to conventional growers.
- A plant pathology team at Parlier, California, provided help and advice to local organic growers about post-harvest diseases. In one effort, the scientists studied packinghouse equipment and treatments to control green mold of citrus. This team also worked with organic growers on post-harvest diseases of other fruits, including peach (*Prunus persica*), grown in the San Joaquin Valley.
- ARS scientists at Fort Pierce, Florida, played a pivotal role in developing a multi-agency group to which Florida's organic growers can turn for help. In current studies, the Fort Pierce team is working with local organic growers to enhance weed and disease control on their vegetable farms. They are experimenting with novel cover crops, paper mulches, soil solarization and biological control agents.

There's more. There is a six-page article in Agricultural Research, February, 2002 entitled 'Organic grows on America' that highlights studies aimed at controlling weeds, boosting plants' nutrition and sidestepping a soybean (*Glycine max*) disease in organic systems, and strengthening the production of organic beef.

To ensure that ARS' organic farming research meets growers' needs, the ARS has established a strong working relationship with the Organic Farming Research Foundation, Santa Cruz, California (www.ofrf.org). This organization conducts surveys and meetings to determine the research priorities of America's organic farmers.

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Increasingly, that research will use today's leading-edge technologies. Global positioning systems, for example, enable growers to customize use of water, fertilizer and biological control agents from one corner of their field to another; and new information about the genetic make-up of plants, animals and microbes can be used by tomorrow organic growers to boost production in environmentall friendly ways.

In the coming months, we will post a new web site on ARS organic farming research.

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Genetically Engineered Organisms: Assessing Environmental and Human Health Effects. Edited by Deborah K. Letourneau and Beth Elpern Burrows. 2002. CRC Press, Boca Raton, FL. 438 p. $74.95, ISBN 0-8493-0439-3.

This book provides in-depth review of a wide range of topics associated with risks of genetically engineered organisms. The book's coverage reflects the distribution of research on risks, with much of the focus being on risks of genetically engineered plants. However, a significant portion of the book also explores topics that have had less synthesis and public discussion until now. Most chapters provide a scientific review as well as a discussion of the implications of the science for risk assessment or policy.

There are eight excellent chapters on risks associated with genetically engineered plants. For readers unfamiliar with these risks, the chapters provide a thorough review of available research and of key issues for risk assessment. For readers more familiar with the topic, the authors often have focused on their own work and that closely related to it, and have provided a very valuable link among the research papers. For example, Joy Bergelson and Colin Purrington have jointly co-authored numerous papers on outcrossing between transgenic plants and wild relatives. In Chapter 2, they weave the experiments they have conducted together in a way that only those involved in the design and implementation of the series of experiments can do. In presenting the research collectively, the chapter provided a perspective that I had not obtained from reading the individual research papers. They particularly stress the need to measure population growth rates of transgenic plants to determine potential weed risks. Chapter 1 gives one an in-depth understanding of the challenges in predicting gene flow as well as the importance of preventing unintentional gene transfer and introgression. The author draws heavily from a re-analysis of her previously published work to illustrate the impact of distance-dependent variability in hybridization rates on attempts to predict rates of transgene spread. In terms of the implications for risk assessment, the upshot is that a single model will not adequately account for the dynamics of both short- and long-distance gene flow.

Five chapters focus on reviewing information about Bt crops and effects of Bt toxin. All of these chapters are an excellent review of issues that have received a lot of public attention. Four chapters include a review of work on Bt corn and monarchs, Bt corn and lacewings, Bt toxin in soils, and the evolution of insect resistance to Bt corn. These chapters serve as an excellent resource for all levels of familiarity, with ongoing discussions of risks of Bt crops. These four chapters are more narrowly focused but provide adequate background and information on the ecological significance of the topic. For example, Chapter 7 provides a case study look at tri-trophic effects of Bt toxin on green lacewings, but also discusses the ecological importance of natural enemies and the data we have obtained from past experiences with pesticides and host plant insect resistance. In contrast to the other four chapters on Bt corn, Chapter 3 provides a broad synthesis of the benefits and risks of Bt crops. The authors discuss economic benefits as well as environmental benefits. They also outline key questions for assessing risks and critically evaluate data available to address these questions. The compilation of available data on the potential for gene flow with wild relatives and non-target effects on lepidopterans, as well as the consequences of these non-target effects, can serve as a model for evaluating simultaneously both single-species effects (lepidopteran use of Bt crop plants) and ecological interactions (lepidopteran's role in regulating plant populations). In addition to outlining available data, the limitations of the data and areas where there are missing data are discussed. While much of the focus of non-target effects of Bt crops has been on the effects of Bt corn on monarchs, this chapter provides compelling reasons for broadening the focus to lepidopteran communities and any consequences of altering lepidopteran communities, rather than focusing on effects on a single species.

Chapter 5 reviews ecological risks associated with crops engineered with virus resistance, namely, the ecological consequences of virus–transgene recombination, of interactions between transgene products and invading viruses, and of hybridization between transgenic virus-resistant crops and wild relatives. In keeping with the other chapters, the author presents a balanced discussion of the data available and what data are not available on these risks. Of particular significance for evaluating risks is that we lack much information about competition among viruses under natural conditions and about the spread of viruses between crops and other plants. A case study of the impacts of the barley yellow dwarf viruses on wild oats and the competitive interactions between cultivated oats and grasses provides an example of information that we need more of. Other notable sections include a discussion of how to reduce risks by choosing or by avoiding particular transgene constructs.

Chapters 9–12 explore topics that have received less attention in recent years, but are likely to emerge as biotechnology continues to develop. I was less familiar with these topics than those on plants, and these four chapters emerged as my favorites.

Chapter 9 discusses risk assessment issues of genetically engineered microorganisms and recombinant DNA. In particular, it provides an excellent overview on the survival and persistence of genetically engineered organisms in different environments (digestive tracts, wastewater and sludge, aquatic ecosystems, soil, plants) and spread of genetically engineered microorganisms by dispersal agents, such as water or animals. Also included is a discussion of the fate of the recombinant genes and the probability of their persistence and subsequent transmission. Not surprisingly, strong similarities in biosafety issues exist among transgenic plants and microorganisms as well as genetically engineered vaccines (Chapter 12). The authors conclude that it will be impossible to limit genetically engineered microorganisms at the point of release. Like the

potential for invasiveness after introducing genetically engineered plants, 'survival and persistence [of genetically engineered microorganisms] are preconditions for developing an impact', and dormancy and the ability to evolve may produce lag times before an impact can be detected.

Chapter 10 was a fascinating discussion of engineering insects for vector-borne disease control for medical, veterinary or agricultural applications. The authors briefly discuss several strategies for controlling insect populations, such as inducible fatality genes, inducible sterility genes, and sterile insect techniques, but the main focus is on explaining general driving mechanisms that could be used in transgenic insects to promote population replacement. An extensive discussion of engineering mosquito vectors to control malaria is used as a case study of how a gene-driving mechanism could alter natural populations of insects. Chapter 11 furthers the discussion of engineering insects to control vector-borne diseases by considering the ethics and human health considerations prior to engaging in these releases. After Chapter 11, one has a much greater appreciation for the complexity of trying to control vector-borne diseases in general and for the challenges involved.

The work on developing genetically engineered vaccines and the potential benefits for human health have received a great deal of attention in the popular press. Chapter 12 provides a thoughtful overview of the risks associated with genetically engineering viruses or using edible transgenic plants as vaccines. As noted earlier, the risks parallel those of genetically engineered plants and microorganisms. However, the authors place much more emphasis on the unpredictability of the risks and hazards associated with genetically engineered vaccines. The chapter also contains a section on horizontal gene transfer that nicely complements the discussion in Chapter 9. The authors very strongly urge a cautious approach to using genetically engineered viruses.

The last two chapters of the book focus on risk assessme Chapter 13 synthesizes Bill Muir and Richard Howard's work methods for assessing ecological risks of transgenic fish releas In particular, they outline four approaches to assessi environmental risks associated with the release of transge fish. They focus much of the discussion on modeling the fate o transgene and have identified a series of life history traits predict the fitness of transgenic fish and subsequent changes gene frequency. Chapter 14 is a fitting final chapter for the boo It offers an overview of the process of biosafety assessment a the areas of disagreement. The author describes in detail t need for thorough guidelines for assessments, full disclosure a transparency, the need for the developers of genetica engineered organisms to have responsibility for demonstrati safety, and the inclusion of a broad group of participants. T author advocates strongly implementing adaptive biosafe assessment and management protocols that will incorpora and integrate relevant information as it develops. Adapti assessments and management create an iterative process that c implement change based on past experience and curre knowledge. The chapter ends with a proposal that indust safety programs for biotechnology be modeled after those engineering industries, such as aerospace and automotive, a outlines the elements of such a program.

The authors and editors of the book have produced extremely valuable contribution to the discussion of enviro mental risks and benefits of genetically engineered organis with retrospective and forward-looking perspectives. The bo will be a valuable resource for those intensely involved in the issues, as well as those casually interested.

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Examples:

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